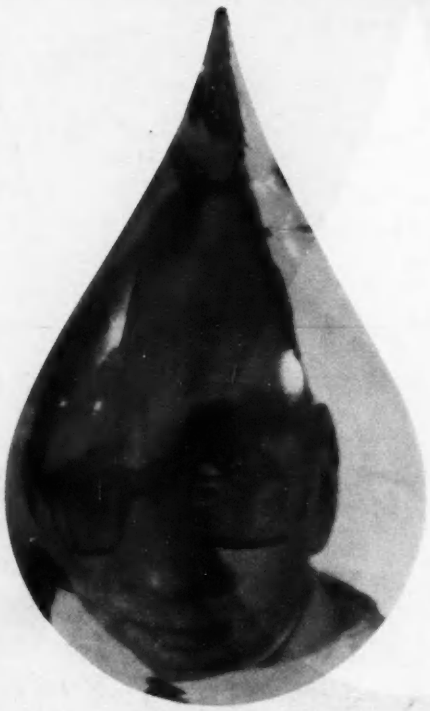
The
ENGINEERS' DIGEST
A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT
VOL. XXII No. 5 MAY, 1961



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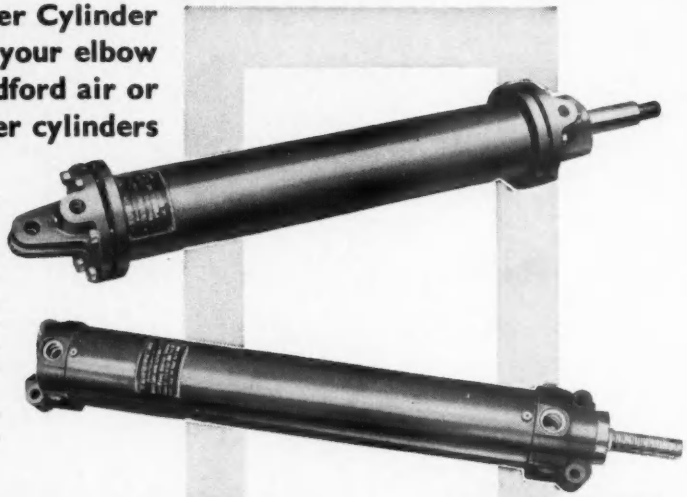

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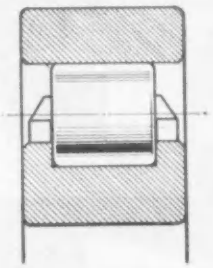

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FROM ALL BOOKSELLERS

The MINIDIGEST

As reported in *Electronics* for March 3, 1961, **strain gauges in the form of silicon-crystal whiskers** are proving useful for detecting weaknesses in mechanical parts and are, in fact, from 50 to 60 times more sensitive than conventional strain gauges. Although other materials also have the property of changing their electrical resistance when slightly compressed or stretched, silicon was selected as the best material for the purpose, as it possesses this property to a greater degree. The whiskers are grown by placing crystals of silicon in one end of a sealed quartz tube and heating it until it vaporizes, the vapour condensing at the cool end of the tube and forming whiskers about 0·5 in. in length and 0·001 in. in diameter, with tensile strengths as high as 10^6 psi.

* * *

Following fundamental investigations carried out in Germany into the **corrosion of metal parts housed in wooden cases,** and reported in *Werkstoffe und Korrosion* for January 1961, it has been established that certain varieties of wood, such as beech and oak, contain up to 5% of combined acids, mainly consisting of acetic acid, which can subsequently be released as a vapour and can attack metals. Tests have shown that the corrosive effects of acetic acid are especially pronounced in air with a relative humidity in excess of 80% as, under such conditions, absorption of water vapour enhances the release of acetic acid, even from woods which appear to be reasonably well-seasoned.

* * *

Designated "Pluton", a **new temperature-resistant organic fabric,** developed by the Minnesota Mining and Manufacturing Co., of St. Paul, Minn., is described in *Materials in Design Engineering* for February 1961. The fabric, which is free from elemental carbon, is claimed to be non-melting at temperatures up to 18,000°F and, although its chemical nature has not as yet been disclosed, it is stated that its fibres are composed of molecules containing carbon, hydrogen, oxygen, and nitrogen. In addition to its exceptional heat resistance, the material, which has a specific gravity of 1·45 and a tenacity of 0·8 gram per denier, also has the advantage of very low thermal conductivity and very high electrical resistivity. Furthermore, it has good resistance to acids, exposure for 100 hr at room temperature to 85% phosphoric acid showing a negligible loss in strength, a 15% loss

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* * *

The results of recent experiments carried out in Japan and reported in the *Journal of the Japan Society of Powder Metallurgy* for December 1960, indicate that additions of zirconium, titanium, boron, or phosphorus result in a marked **improvement in the magnetic properties of sintered permanent magnets.** It should, however, be noted that these additions can have various effects on the structure of such magnets. Thus, while titanium exercises only a slight effect on grain size, zirconium tends to induce grain growth. Small additions of boron or phosphorus result in grain growth; large additions cause the appearance of a eutectic structure on the grain boundaries of the magnets.

* * *

Utilizing thin interlocked fibres of metal, a new welding process, designated **fibre-metal resistance welding,** has been developed at the Armour Research Foundation in Chicago, Ill., and is stated to promise improved efficiency in spot, seam, and projection welding, with lower power requirements than conventional resistance welding. In this process, which also offers the possibility of making resistance welds of high-conductivity metals such as copper, fibre-metal sheet is used between the surfaces to be welded, with the result that the ratio of contact resistance to bulk resistance is greatly increased, the metal in the fibre mat reaching its melting point more quickly, while the base metal remains relatively cold.

* * *

Basically intended for testing the practicability of air-conditioned attire for military personnel, an experimental **self-contained, thermoelectric-type air-conditioned suit** has been developed by the Westinghouse Electric Corporation and the U.S. Naval Supply Research and Development Facility. Cooling is effected by passing current through thermoelectric couples made of semiconductor-type materials, reversal of the current producing heating, instead of cooling. Both heating and cooling are carried out automatically, and tests show that a temperature of about 80°F is maintained in the

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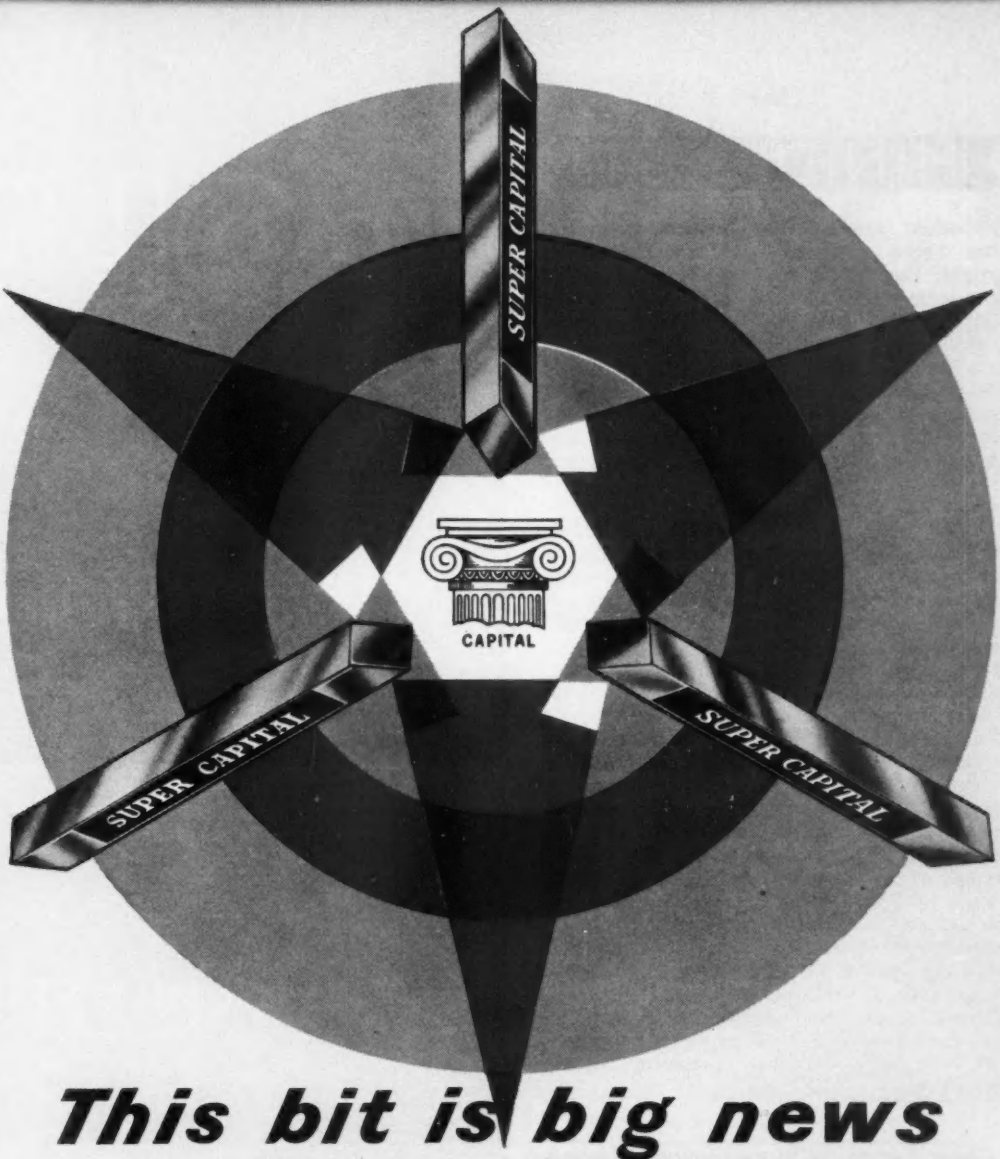

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The MINIDIGEST

suit when the external temperature varies from about −40 to +135°F. Completely airtight, the suit is made from an insulated aluminium-coated fabric, air for breathing being supplied through a face-mask connected to the side of the suit helmet, where incoming air is heated or cooled by a small heat exchanger. The only moving parts are two small fans for circulating the conditioned air around the wearer, batteries permitting the suit to be used for one hour without any other power source.

* * *

It is known that the electrical conductivity of polycrystalline cuprous oxide decreases on heating to 150°C and that conductivity shows a marked and permanent increase as a result of intense illumination. These results have been explained by the dissociation of impurity centres, i.e., vacancies left by copper ions, during illumination and their association during heating and, if these assumptions are correct, the effects noted should increase, together with the concentration of the defects. For this reason, tests carried out to determine whether the same results can be observed on single crystals are concerned with the **effect of excess oxygen on the electrical conductivity of pre-illuminated and heated single crystals of cuprous oxide,** the change in concentration of defects being achieved by annealing the samples at various pressures of oxygen at a temperature of 960°C. The results of these tests, reported in the *Czechoslovak Journal of Physics* (No. 2, 1961), show that the influence of illumination on electrical conductivity, together with the concentration of impurities, increases with increasing oxygen pressures during annealing.

* * *

According to the Russian journal, *Svarochnoye Proizvodstvo*, for April 1961, the use of a **special electrode for the manual arc-welding of nickel** has overcome the difficulties normally encountered when welding this material. The electrode is made of a nickel wire, from 3 to 5 mm in diameter, coated with a composite material containing titanium dioxide, barium fluoride, sodium fluoride, sodium oxide, manganese, titanium, aluminium, and sodium silicate. It is claimed that weld deposits of high mechanical strength, free from pores and inclusions, can be achieved with this electrode, which also ensures easy ignition and a high stability of the arc during welding.

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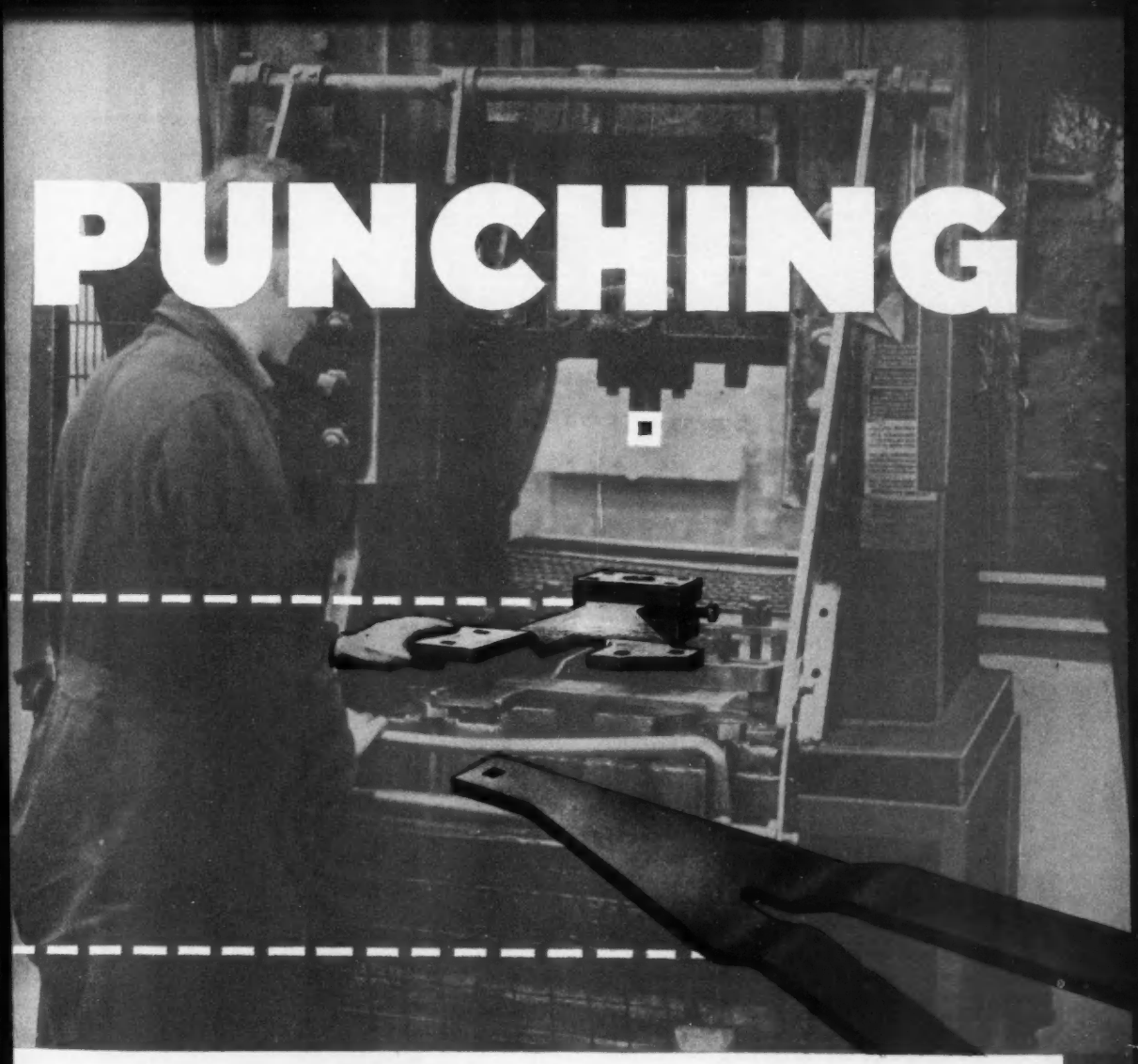

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BUSINESS NOTES

The electronics sections of **Armstrong Whitworth Aircraft Ltd.** and of the **Brush Electrical Engineering Co. Ltd.** have been linked to form a partnership, known as **Armstrong Whitworth/Brush,** to manufacture and market advanced electronic and electrical-control and intelligence systems. Brush will be the trading organization for the new partnership and will work in close co-operation with the sales staff of Armstrong Whitworth equipment, enquiries for electronic equipment being channelled to whichever of the two companies has the more suitable facilities.

* * *

Cranes (Dereham) Ltd. announce that, with the participation of the **Wall Engineering Co.,** they have entered into negotiations with **Fruehauf International,** a subsidiary of the **Fruehauf Trailer Co.,** of Detroit, Michigan, to form a new company at North Walsham for the manufacture of trailers and semi-trailers embodying the designs and specifications of both Fruehauf and Cranes. The latter company manufactures and supplies standard and specialized trailers and semi-trailers to most world markets, while the Fruehauf Trailer Company is the largest manufacturer of trailers in the world.

* * *

Following the closure of their premises at Ledsam Street, Birmingham, **James Archdale and Co. Ltd.,** one of the machine-tool companies in the **Staveley Group,** announce that their sole address is now Blackpole Works, Worcester. (Tel: Worcester 27081).

* * *

Royston Instruments Ltd., of Byfleet, makers of the "Midas" magnetic-tape flight-recording system, have granted a manufacturing licence to **Lockheed Aircraft Services,** of California, under which the American company will produce and market this equipment in the Western hemisphere and in Australasia. This licence is an extension of a previous agreement between the two companies, made in April 1960, when Lockheeds were appointed agents for the Midas equipment, in which there is strong U.S. military interest and for which plans are afoot for fitting these recorders in American aircraft.

* * *

The Federation of **British Rubber and Allied Manufacturers** has moved its offices to 19/20 Berners Street, London, W.1. The telephone numbers (MUSeum 2671 and 0268) remain unchanged.

* * *

An exclusive agreement has been signed between the **Birmingham Tool and Gauge Co. Ltd.,** of Soho Hill, Birmingham 19, and **Madison Industries Inc.,** of Providence, Rhode Island, for the manufacture and distribution of the latter company's complete range of special tooling, covering the machining of holes from drilling to super-finishing. The range of products manufactured by the Birmingham Tool and Gauge Co. Ltd. includes a wide variety of small tools, press-shop equipment, and special-purpose machine tools, while the specialized tools produced by the American company include

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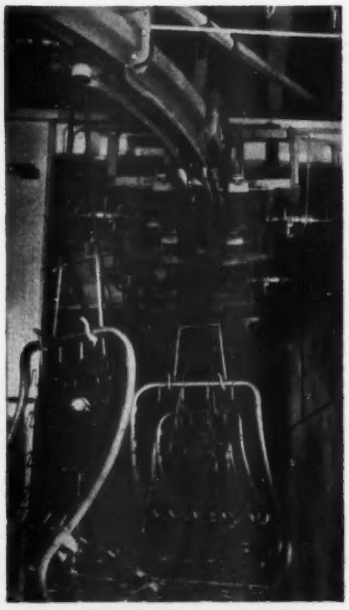

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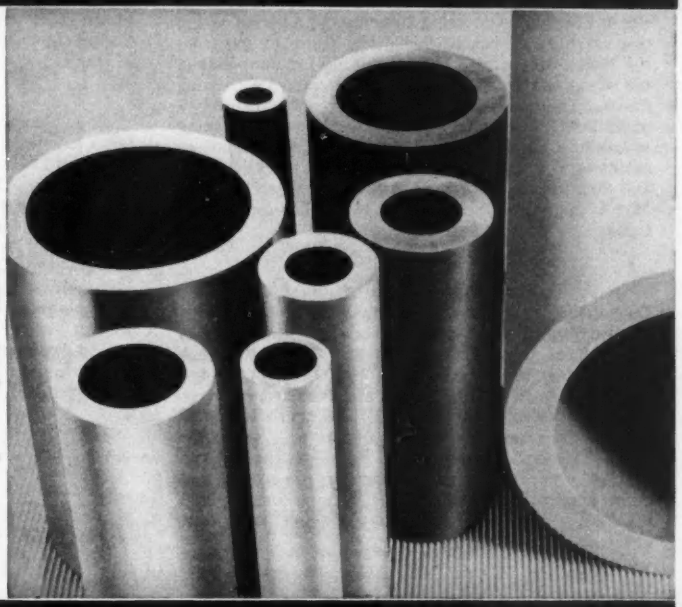

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BUSINESS NOTES

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* * *

The **Kestner Evaporator and Engineering Co. Ltd.** are transferring their London works from New Cross to a site at Greenhithe covering 10 acres and adjacent to the new Dartford tunnel, so that direct access to and from the North can be made by by-passing London, though the works will be easily accessible by rail from Charing Cross. The new works will gradually be brought into operation, commencing in June, 1961, completion being scheduled around the end of the year, and will include an extensive new laboratory with facilities for pilot-plant and experimental testing. The old Kestner works in the New Cross area will be acquired by the London County Council for demolition.

* * *

It is announced by **British Insulated Callender's Cables Ltd.** that they have formed a new company, **Telcon Plastics Ltd.,** to take over the entire range of activities of the Plastics Division of **The Telegraph Construction and Maintenance Co. Ltd.** The new company, which will be centred at Green Street Green, Orpington, Kent, will continue to manufacture and develop the range of plastics products with which the name "Telcon" is associated, including the plastics coating of papers, plastics powders for dip-coating and other applications, sheeting for vacuum-forming and fabrication, and coated materials and laminates for use in specialized packaging.

* * *

KABI (Electrical and Plastics) Ltd., of Cranborne Road, Potters Bar, Middlesex, announce that their telephone number has now been changed to Potters Bar 53444.

* * *

It is announced by the **Dunlop Rubber Co. Ltd.** that agreement has been reached with the Government of the Federation of Malaya for the company to establish a tyre factory for the production of a wide range of truck, motorcycle, and bicycle tyres. The new factory will be built on a site already acquired at Petaling Jaya and is expected to be completed by the end of 1962. When in full operation, it will provide employment for about 600 persons.

* * *

As a result of collaboration between **Shephard, Hill & Co. Ltd.,** civil-engineering contractors, and **Norstel & Templewood Hawksley Ltd.,** a **Hawker Siddeley Industries** company, a new organization, **Anti-Pollution,** with offices at Central Chambers, Ealing, London, W.5, has been set up to provide a comprehensive contract service for the treatment of liquid trade waste. The new organization offers full facilities for project analysis, experimentation, and design, followed by full-scale construction of treatment plant, including the design and production of mechanical and electrical process plant and all civil-engineering requirements. In addition, Anti-Pollution can undertake to put the plant into service and initially to control its operation, while the specialist resources of **Activated Sludge Ltd.,** a subsidiary of Norstel & Templewood Hawksley Ltd., are also available in connection with biological treatment problems.

* * *

The **Elgar Machine Tool Co. Ltd.,** of 172/178 Victoria Road, Acton, London, W.3 (Tel: ACOrn 5555) have been appointed sole distributors in the U.K. of the Model-2000 horizontal precision boring machine manufactured in Italy by **Fabbrica Macchine Industriali,** of Naples.

* * *

A new company, to be called **Nuclear Developments Ltd.,** has been formed jointly by **Imperial Chemical Industries Ltd. (Metals Division), Rolls-Royce Ltd.,** and **The Rio Tinto Co. Ltd.** Each of these three companies has experience which will be appropriate to the future role of the new company in nuclear engineering. Thus, the I.C.I. Metals Division has made several contributions to technological progress in nuclear engineering over the past twenty years and has exceptional facilities for the manufacture of nuclear metals and reactor components, while Rolls-Royce has been engaged in the nuclear field for the past eight years and has a specific interest in marine nuclear propulsion, and the Rio Tinto Co. mines, extracts, and processes uranium on a large scale.

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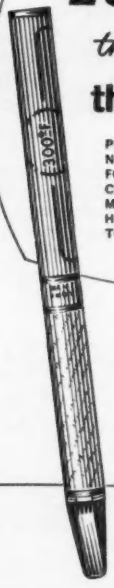

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CONTRACTS

A contract worth £500,000 for eight dust-collecting plants has been signed in Moscow by Tilghman's Ltd., of Altrincham, a member of the Staveley Group of companies. This equipment, which will be utilized for the purification of the hot exhaust gases from carbon-black production units, has been bought by the Soviet Techmash trading corporation, and it is understood that half are intended for a car factory being built at Dniepopetrovsk in the Ukraine and the other half for works in Rostov.

* * *

Since January 1961, orders for thirty buried-type transformers, valued at about £50,000, have been placed with Ferranti Ltd., of Hollinwood, Lancs., by the South of Scotland Electricity Board. These orders cover the supply of twelve 500-kVA and seventeen 1000-kVA, three-phase, 50-cps, oil-filled, Class "A" insulated units, and one 500-kVA dry Class "C" insulated unit. Buried-type transformers represent a convenient method of reinforcing existing electricity networks supplying large numbers of small consumers in built-up areas, as they have the advantage that no objections can be raised to their use from the aesthetic viewpoint since the transformer core and windings are contained in a strongly protected tank which can be buried directly in the ground, e.g., under a pavement or grass verge, with only a comparatively small ventilating pillar showing above the surface. Also, as the pillar can be installed in a wall or hedge, it blends unobtrusively with its surroundings, so that the whole arrangement eliminates to a great extent the aesthetic problem of enclosures associated with above-ground oil-filled transformers.

* * *

Contracts, valued at £400,000, have recently been received by Davey, Paxman & Co. Ltd., of Colchester, from the Victoria Machinery Co. Ltd. and the Burrard Dry Dock Co. Ltd., of Vancouver, B.C., Canada, for the supply of the propulsion and electrical generating machinery for two new 3000-ton twin-screw ferry-boats to operate between Swartz Bay, near Victoria, and Tsawwassen, near Vancouver. Propulsion power, totalling 6000 shp, for each vessel will be provided by four 16-cylinder Paxman diesel engines, and electrical power, amounting to 1500 kW, by three 12-cylinder diesel-generator sets. In addition, each vessel will have a 150-kW Paxman generating set for harbour and auxiliary duties.

* * *

The Fraser & Chalmers Engineering Works of the General Electric Co. Ltd. has received an order exceeding £150,000 from the Anglo-American Corporation of South Africa Ltd. for two complete double-drum winding-engines for the main sub-incline shaft of Bancroft Mines Ltd. in Northern Rhodesia. These units, one of which will be used for handling rock and the other for winding men and materials, will be installed in an underground chamber 1150 ft below the surface. Each drum will be 11 ft in diameter and 4 ft in width, and the engines, which will be fitted with G.E.C. low-

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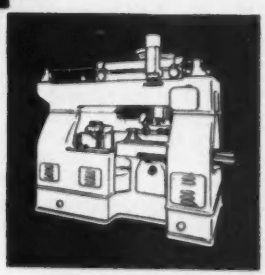

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CONTRACTS

pressure oil-operated brakes, will be driven through single-reduction gears by 11-kV, three-phase, 1440-hp, 570-rpm motors.

In addition, The General Electric Co. Ltd. has recently received a repeat order, valued at £139,000, for the supply and installation of a second 100,000-cfm turbo-blower at the Cleveland Works of Dorman Long (Steel) Ltd. This machine, and the other machine already under construction at the Fraser & Chalmers Engineering Works will be installed alongside two existing 90,000-cfm blowers also supplied by the company.

* * *

Hayward Tyler & Co. Ltd., one of the Stone-Platt group of companies, have been awarded a contract, valued at about £50,000, by Simon Carves Ltd. for the supply of eight low-pressure and eight high-pressure glandless circulating pumps for the G.E.C.-Simon Carves nuclear power station under construction for the Japanese Atomic Power Co. at Tokai Mina.

* * *

An order for diesel generating plant, worth over £250,000, has been received by Mirrlees, Bickerton & Day Ltd. from the Government of the Province of Santa Fe, Argentina. The order involves the supply of four Mirrlees KVSS 12-cylinder engines with HSBT super-chargers, directly coupled to Brush alternators, each set developing 2196 kW at 428 rpm. In this connection, it is interesting to recall that trading relations between Mirrlees and Argentina date back to 1912, when the company supplied one of the first British engines ever exported, and that more than 250 Mirrlees diesel engines have been supplied to Argentina since 1946.

* * *

The English Steel Corporation Ltd. has placed an order worth nearly £1,000,000 with the Heavy Plant Division of Associated Electrical Industries Ltd. for electrical equipment for four rolling mills to be installed at the Corporation's new Tinsley Park Works, Sheffield. The equipment will include two 3500-hp d.c. motors for the twin drive of a 42-in. blooming and slabbing mill to be supplied by the Davy and United Engineering Co. Ltd. and the Brightside Foundry & Engineering Co. Ltd., who are acting together as a consortium. These two motors will be installed with the upper motor nearer the mill than the other—a "top-forward" arrangement pioneered in the U.K. by A.E.I. Two 32-in. billet mills, also to be supplied by the consortium, will be equipped with A.E.I. motors, one of 4000 hp and the other of 5000 hp. The bar mills, for which the complete order has gone to The Brightside Foundry & Engineering Co. Ltd., will comprise a reversing roughing mill driven by a 2000-hp motor, an intermediate mill driven by a 1000-hp motor, and a continuous mill driven by five 450-hp motors and two 350 hp motors. In addition to the main motors, A.E.I. will supply and install steel-tank mercury-arc converters for supplying power for the d.c. motors, as well as all the requisite d.c. circuit-breakers, open-type slate motor control panels, motor supervisory cubicles, electronic controls, and magnetic amplifiers.

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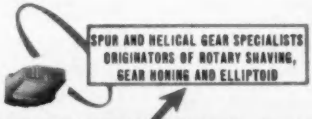

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PERSONAL

G. and J. Weir Holdings Ltd., of Cathcart, Glasgow, announce the appointment of **Mr. J. W. Atwell, M.Sc.,** as an additional director. Mr. Atwell is managing director of the principal operating subsidiary company of the group, G. and J. Weir Ltd.

* * *

Renold Chains Ltd., of Wythenshawe, Manchester, announce that **Mr. L. J. Tolley,** at present works director, has been appointed a deputy managing director, additional to **Mr. W. S. C. Tully,** while **Mr. E. E. Hempsall** has been appointed general works manager in succession to **Mr. L. J. Tolley.** In addition, **Mr. J. A. Ford,** home sales manager, has been appointed sales director of Renold Chains (Sales) Australia Pty. Ltd. **Mr. F. T. Standford** will succeed Mr. Ford as home-sales manager, while **Mr. A. E. Clough** has been appointed commercial sales manager (home) in succession to Mr. Stanford.

* * *

Mr. A. M. Browne, B.Sc., A.R.C.Sc.I. has been elected president of The British Electrical and Allied Manufacturers' Association (BEAMA), while **Mr. H. H. Mullens, B.Sc., M.I.E.E.,** has been elected deputy president. Mr. Browne is chairman and managing director of the Hackbridge and Hewittic Electric Co. Ltd. and chairman of Combined Electrical Manufacturers Ltd. Mr. Mullens is chairman and managing director of A. Reyrolle and Co. Ltd. and chairman of C. A. Parsons and Co. Ltd.

* * *

Osma Plastics Ltd., of Isleworth, Middlesex, announce that **Mr. L. F. Bull,** who has held the post of general manager (production) since 1957 and is responsible for product development, production, and technical service, has been appointed a director of the company. **Mr. R. A. Richardson,** who holds the position of sales manager, Building Division, has also been appointed a director, and, as such, his work also entails responsibility for the newly formed Industrial Division of the company.

* * *

Mr. C. St. C. Proctor, F.C.A., has been appointed to the board of S. Smith and Sons (England) Ltd. as financial director. **Major C. M. Carrington, M.C.,** formerly chairman of K.L.G. Sparking Plugs Ltd. and a director of K.L.G. from 1918 to 1956, has retired from the Board of S. Smith and Sons (England) Ltd.

* * *

Mr. I. A. Bailey has been elected a vice-president, and **Mr. J. O. Hitchcock** an assistant vice-president, of The International Nickel Company of Canada Ltd. Mr. Bailey remains chairman and chief officer of The International Nickel Co. (Mond) Ltd. and of Henry Wiggin and Co. Ltd., while Mr. Hitchcock continues to be managing director of The International Nickel Co. (Mond) Ltd. and deputy chairman of Henry Wiggin and Co. Ltd., as well as second chief officer of both companies. In addition, **Mr. H. W. G. Hignett,** who

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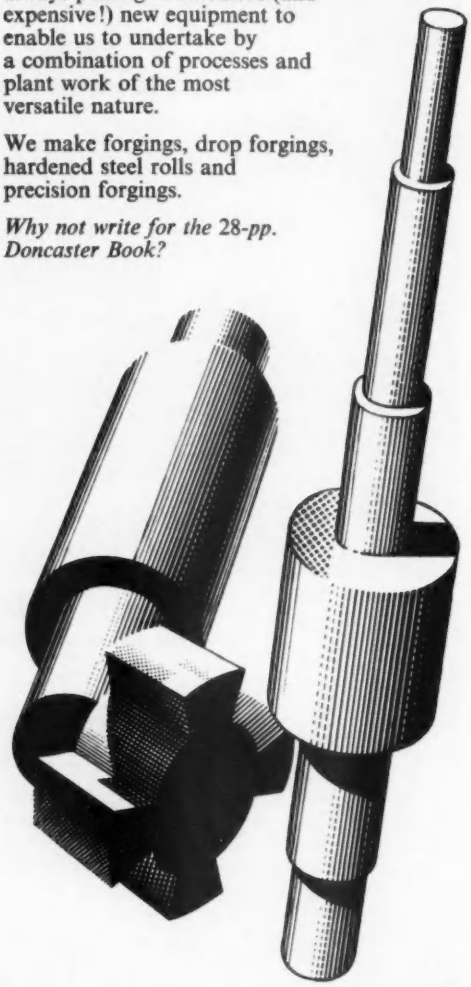

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PERSONAL

remains managing director of Henry Wiggin and Co. Ltd., and **Mr. J. M. Dhavernas,** who is located in Paris and has been closely concerned for many years with nickel markets on the Continent, have both been appointed directors of The International Nickel Co. (Mond) Ltd.

* * *

Following the retirement of **Mr. W. C. M. Matterson,** founder and managing director of Matterson Ltd., the mechanical-handling engineers, of Rochdale, Lancs., his son, **Mr. R. Kelvin Matterson,** who has been joint managing director since 1957, has now succeeded him as managing director.

* * *

Mr. J. E. Yates has been appointed to the board of Lancashire Dynamo and Crypto, a company in the Metal Industries Group.

* * *

Following his election to the board and his appointment as general manager of Lang Pneumatic Ltd., of Wolverhampton, **Mr. G. E. Jowitt** has resigned from his position as secretary of the company, his place being taken by **Mr. G. H. Oxborrow.**

* * *

Mr. H. L. Satchell, M.B.E., F.I.W.M., director of manufacture of Associated Electrical Industries (Rugby) Ltd., has retired after 41 years of service with the company.

* * *

It is announced by The General Electric Co. Ltd. that **Mr. W. A. C. Maskell, B.Sc.(Eng.), M.I.E.E.,F.B.I.M., Sen.M.I.R.E.,** general manager of the company's Telecommunications Group at Coventry since 1955, has been appointed managing director of the Group.

* * *

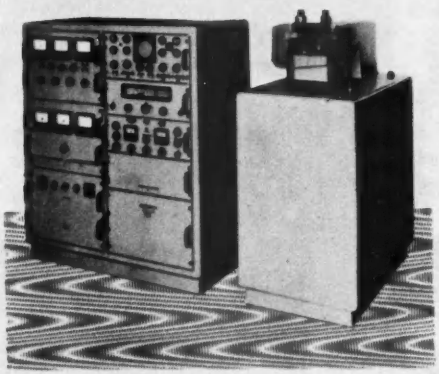
Mr. St. John de H. Elstub, C.B.E., has been appointed chairman of the Metals Division of Imperial Chemical Industries Ltd., in succession to **Mr. M. J. S. Clapham,** who has joined the company's main board as an overseas director. Mr. Elstub is chairman of Amal Ltd., an I.C.I. subsidiary, and a director of Yorkshire Imperial Metals Ltd., which is operated jointly by I.C.I. and Yorkshire Copper Works (Holdings) Ltd. **Mr. W. H. G. Lake, O.B.E., Ph.D.,** has been appointed joint managing director (technical) of the Metals Division of I.C.I. in succession to Mr. Elstub.

* * *

MR. F. ARCHDALE

It is with deep regret that we record the death on April 18, 1961, while on holiday in Spain, of Mr. Fred Archdale, a director of James Archdale & Co. Ltd., of Worcester, at the age of 68.

TURBO 4



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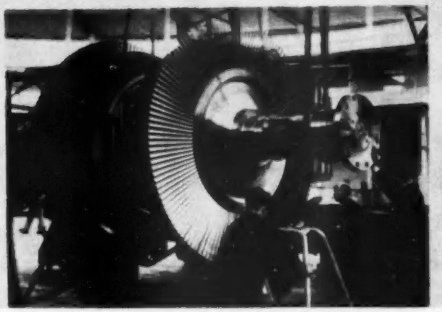

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NEWS ROUND-UP

Film on the Manufacture and Applications of Hard Metals

Shot at the Rainham Works of Murex Ltd., the new film, "Hard Metal" (2nd edition), has been produced to replace the original film of the same name presented by Murex Ltd. in 1950, and shows in great detail the complete manufacturing process concerned in the production of hard metal, from the treatment of wolfram and scheelite ores to the production of finished tungsten carbide tips, tools, and dies.

Judiciously interspersed with diagrams to illustrate each phase of the complex processes involved, the film follows the progress of the ore concentrates through a number of large chemical plants, including the reduction of pure tungstic acid, and then shows and describes every stage in the manufacture of cemented tungsten carbide. In addition, the various machines and methods used to produce finished tools and dies are shown, and examples are given of the wide field of application of this material in modern tooling, together with examples of tungsten carbide tooling at work in industry.

Copies of this new film, which has a running time of about 50 minutes, as well as copies of two previous films, i.e., "Milling Cutters" and "Lathe Tools", are available for screening by the company's technical staff in customers' works, or on free loan to technical colleges and other interested organizations. Applications should be made to the relevant regional-area offices, i.e., at Central House, Upper Woburn Place, London, W.C.1; at Norwich Union Buildings, City Square, Leeds 1; or at Guildhall Buildings, Navigation Street, Birmingham 2.

European Symposium on Space Technology

As already announced in our issue of February 1961, a European Symposium on Space Technology is being organized by the British Interplanetary Society and will be held in the Council Room of the Federation of British Industries, 21 Tothill Street, London, S.W.1, from June 26 to 28, 1961.

The purpose of the Symposium is to draw attention to the following:—

(1) Future trends in the development of space-flight, particularly a review of future possibilities related to West-European capabilities, but taking into account advanced studies which need not call for very considerable budgets, e.g., structural and propulsion problems, and control engineering.

(2) Applications of space technology in the civilian field, e.g., communication and meteorological satellites.

(3) Papers dealing with the effect of space technology on the present structure and level of industry, particularly of an international nature, with consideration of the political and economic aspects.

The first two days of the symposium will be devoted to technical papers in connection with Nos. (1) and (2) above, but the third day will be devoted to discussion papers as set out in No. (3) above. Pre-prints of all papers of types (1) and (2) are likely to be available approximately one week beforehand, but synopses only

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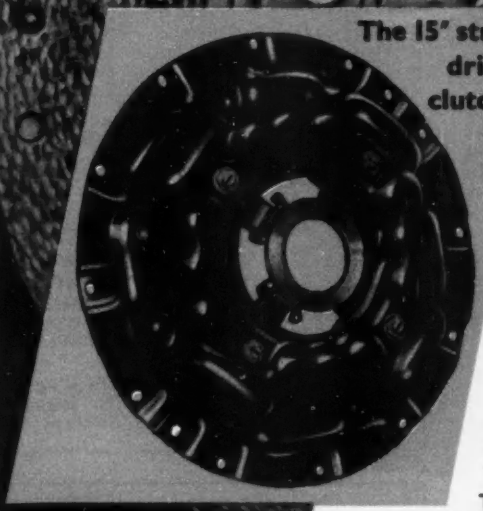

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of type (3) papers will be read, the greater part of the meeting being given over to general discussion of the ideas put forward. In view of the importance of the proceedings, simultaneous translation facilities will be provided in English, French, and German, and full press facilities will be extended to accredited representatives.

It should be stressed that the symposium envisaged will differ to some extent from normal symposia, which consist only of the presentation of technical papers. On this occasion, an opportunity is being taken to promote discussion, to pose problems, and to ascertain to some extent the probable lines of development both in international politics and industrial collaboration for the development of a basic structure of space technology for West-European nations. In addition, the symposium is being convened in the hope that the realization that a new surge of technical progress is gathering momentum may become more generally appreciated.

Further information can be obtained on application to Mr. L. J. Carter, Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, S.W.1 (Tel: TATe Gallery 9371).

Large Gear-Type Flexible Couplings for Steel Converters

Certainly the largest of their type ever designed and made by Crofts (Engineers) Ltd., of Bradford, Yorks., and probably the largest ever made anywhere, three internal-gear flexible couplings are being constructed for use in the new steelworks of Richard Thomas & Baldwin, at Newport, Mon. In this works, the L-D oxygen-blown steelmaking process will be employed, and the great steel converters used will be electrically tilted, the drive being engaged through these flexible couplings. Each coupling is about 73 in. in diameter and weighs nearly 12 tons, with an equivalent rating of 45,000 hp at 100 rpm. The gear teeth are barrelled to accommodate considerable misalignment.

Guide to Arc-Welding Electrodes

The British Electrical and Allied Manufacturers' Association have published a new and completely revised 100-page edition of their "Guide to Arc-Welding Electrodes", which is designed to assist the user in the choice of suitable electrodes for each purpose. The guide was first published in 1944, and this is the sixth edition, which gives in a convenient form classified lists of British electrodes and a key to American and British Electrode Standards.

To assist consumers in choosing the currect electrode for a particular application the guide includes a brief description of the British Classification of Electrodes, published in B.S. 1719 : 1951. In this issue, a more complete description of the American method of classifying electrodes is given, and the equivalent American Code numbers are shown in all the classified lists. For those interested in electrodes for welding non-ferrous metals, cast iron, and corrosion-resistant and other steels, a section is included which gives information on special electrodes and lists of the special electrodes available.

Copies of the Guide, price five shillings, are available from The British Electrical and Allied Manufacturers' Association, 36 Kingsway, London, W.C.2.

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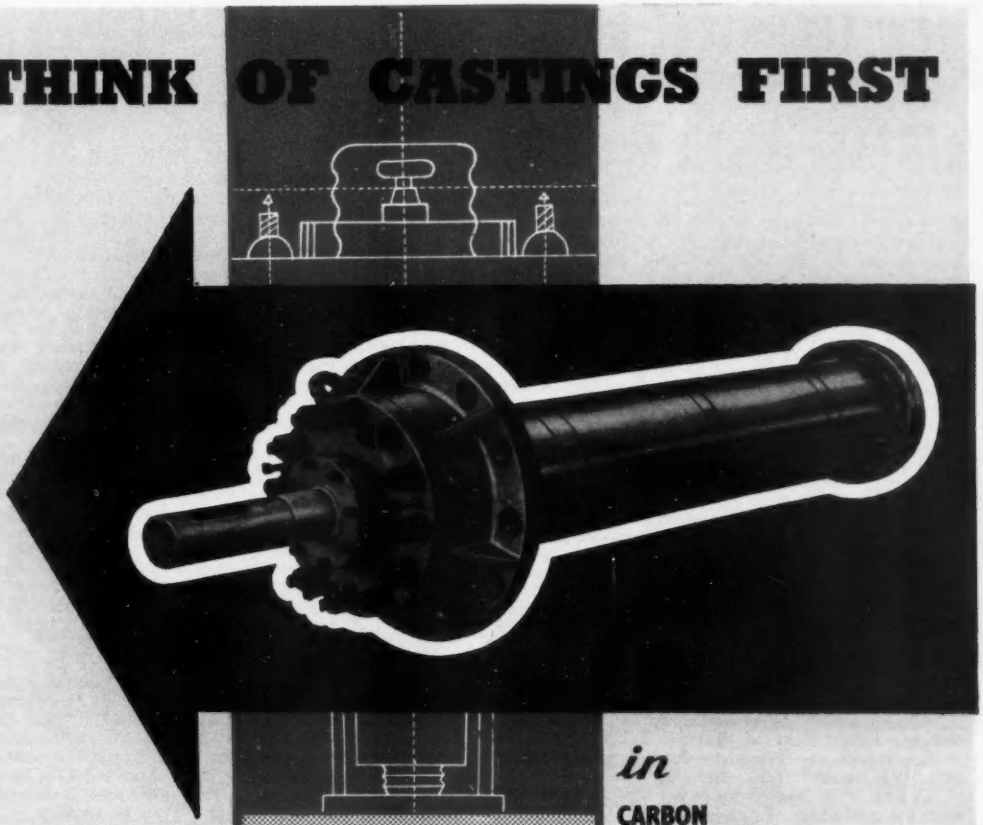

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NEW TECHNICAL BOOKS

British Plastics Year Book, 1961. 31st edition. 712 pages. Published by Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 45/– (postage 2/–).

Constituting the only comprehensive classified guide to products and manufacturers in the British plastics industry, this useful book is, as always, full of invaluable information for all connected with plastics and for manufacturers and users of machinery and equipment.

The book is divided into sections, each conveniently located by a tabbed card, and includes comprehensive classified lists of manufacturers and suppliers and materials, finished products, and equipment, as well as the largest list in the world of trade and proprietary names connected with the industry, each trade name being followed by a definition of the product and the manufacturer concerned. Another section (new in this edition) lists those companies who give basic services, ranging from moulding and extruding to welding and metallizing, while the names-and-addresses section contains over 7000 firms associated with plastics, those in the U.K. and overseas being listed separately. All these lists, including a "Who's-Who" section, giving the names and positions of prominent people actively engaged in the industry in the U.K., have been thoroughly revised and extended. Similarly, the sets of tables giving the comparative properties of plastics materials have been revised and brought up to date, as also has the glossary of technical terms, the lists of new companies registered during 1960, and the specifications relating to plastics.

Increasing the Loading on Gearing and Decreasing its Weight. Edited by M. M. Saverin. 212 pp., 86 illustrations. Publishers: Pergamon Press Ltd., Headington Hill Hall, Oxford. Price: 70/–.

In view of the importance of any work in connection with the possibility of bringing about a simultaneous reduction in the weight and an improvement in the performance of machines, there can be no doubt that this English translation of a collection of Russian articles on the subject will prove of considerable interest to designers and investigators working on the dynamics of gear transmissions.

Constituting a guide to Russian activity in this field, the book presents in eight different articles, each written by an expert, the results of research undertaken in Russia to find the most efficient ways of running gear transmissions to perm t full use of their load-carrying capacity and to reduce their weight. The subjects covered include details of a number of reduction gears at present in use in several rolling-mill plants and an analysis of their performance; measures taken to lower the weight of reduction-gear units by a rational choice of parameters; constructional improvements in casings and gearwheels in reduction-gear units, with a view to lowering their weight; loading conditions and load-bearing capacities of the surfaces of gear teeth; the load-carrying capacity of gears with extended centre distance meshing with zero total displacement of the original contour; the load-carrying capacity of gears with extended centre distance meshing with a large positive total displacement; problems connected with dynamic loads on the teeth of spur-gear transmissions; and an experimental determination of the rigidity of gear teeth.

Metal Industry Handbook and Directory, 1961. 50th edition. 560 pages. Published by Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 21/– (postage 1/9).

Offering in one convenient volume comprehensive information to all those who are engaged in or who are connected with the non-ferrous metal industries, this handbook and directory provides all essential details of the newer, as well as the more familiar, metals and alloys and their applications, including zinc diecasting alloys, solders, brazing alloys and fluxes, fusible alloys, and white-metal bearing alloys. In addition, all relevant British Standard, D.T.D., and Admiralty specifications are included, together with an extraordinarily comprehensive list of proprietary alloys.

Other sections are devoted to general data and tables in connection with non-ferrous materials in the form of sheet, rods, bars, tubes, etc., and to electroplating and allied processes, ranging from plant, plating solutions, and rates of deposition to the common and chemical names and formulae of substances used in the plating trades. In addition, there is a useful directory containing lists of trade names, metal and allied-trades associations and societies, scientific and technical institutions, and a classified directory for buyers.

A Guide to Technical Writing. By C. Baker, A.R.Ae.S. 111 pp., 11 illustrations. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, London, W.C.2. Price: 15/–.

The author states in his preface that this guide is not a complete treatise on technical authorship and illustration, and then proceeds to cover far too wide a field in far too little space. True, much of what he says is admirably expressed, and one can find little to criticize in his treatment of such matters as illustrations, preparing copy for publication, reproduction, and economics and management. Unfortunately, he appears to have forgotten that his book is supposed to be a guide to technical *writing* and, although most facets of this aspect are satisfactorily covered, they are in a few instances over-condensed. Thus, in his chapter on English composition and grammar, he gives one example of part of a technical write-up and explains how it can be improved by redrafting in a more factual style. One of the results of this redraft is the unwitting inclusion of a glorious *non sequitur* which merely emphasises one of the very faults the author is trying to warn the reader to avoid. If more than one example had been included in this section, the gist of what the author was really intending to convey would have been more clearly shown.

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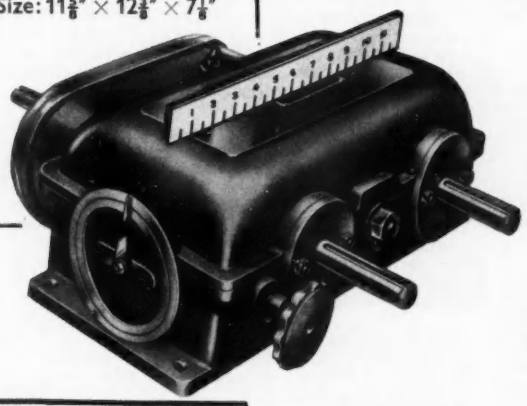

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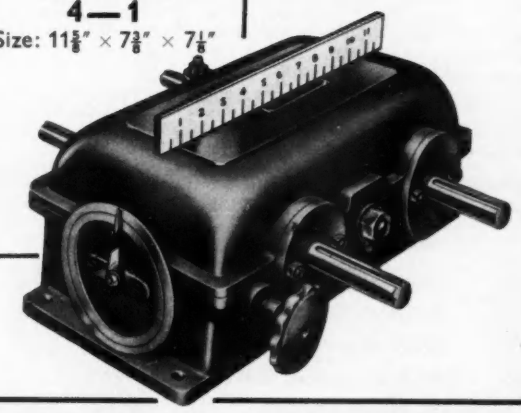

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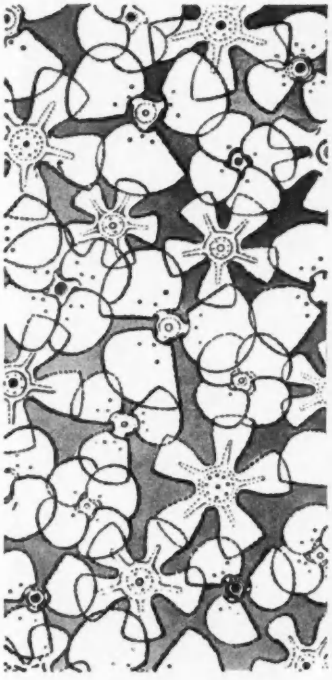

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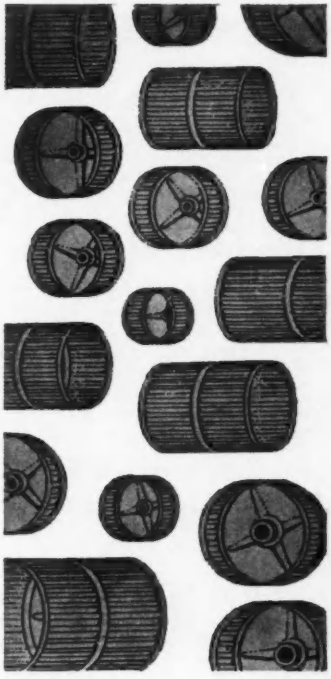

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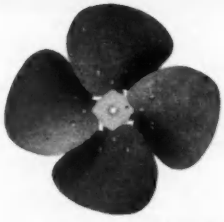

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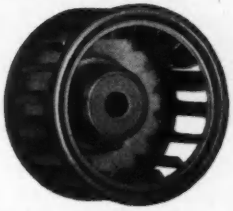

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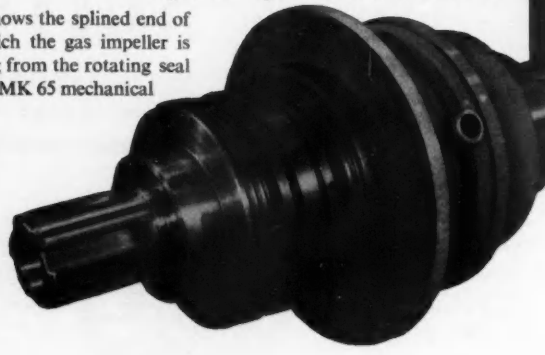
Top Left: Two of the steam raising units are shown here already in position against the background of the general construction work in progress.

Right: The complete impeller shaft assembly is shown alongside the domed end impeller casing in which it will be installed.

Below right: This shows the splined end of the shaft upon which the gas impeller is mounted, projecting from the rotating seal face of the CRANE MK 65 mechanical shaft seal unit.



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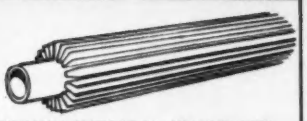

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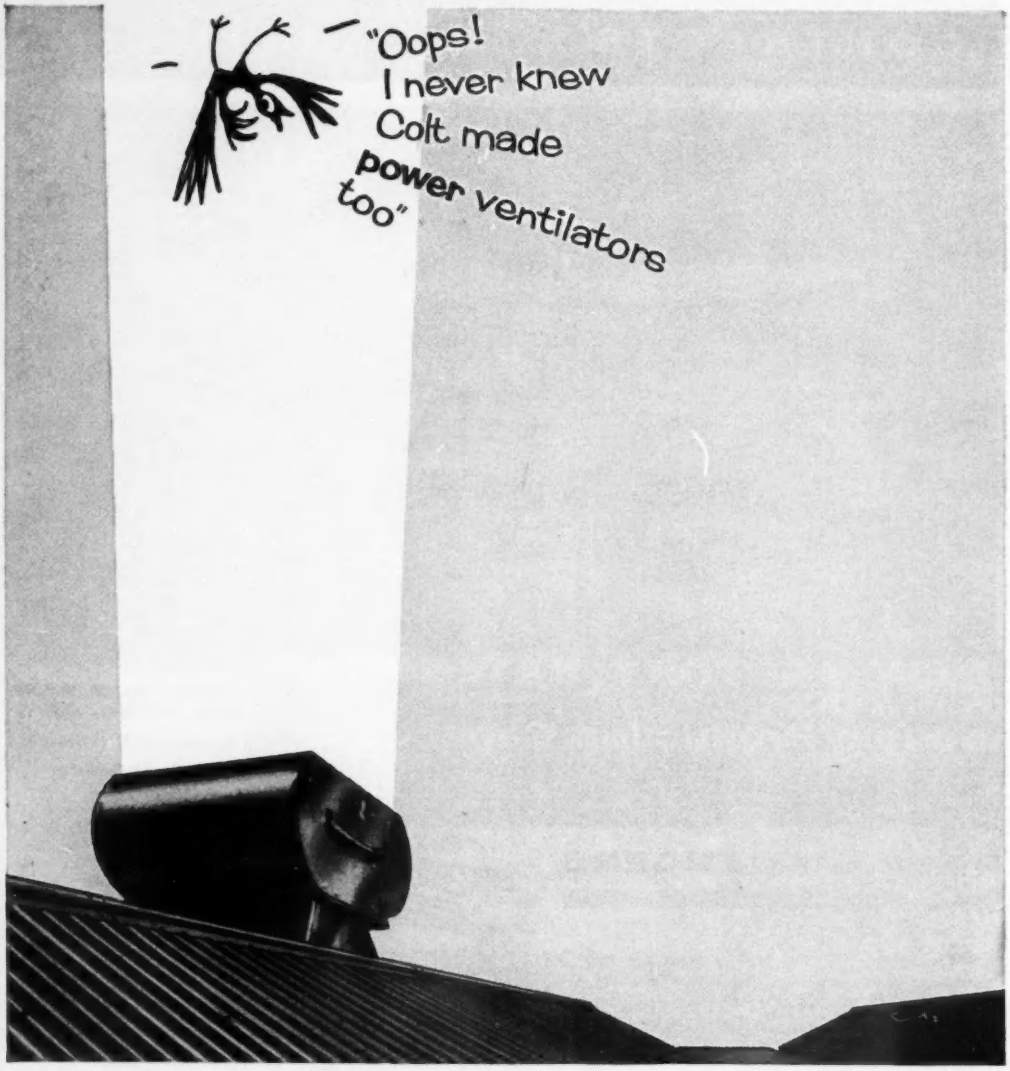

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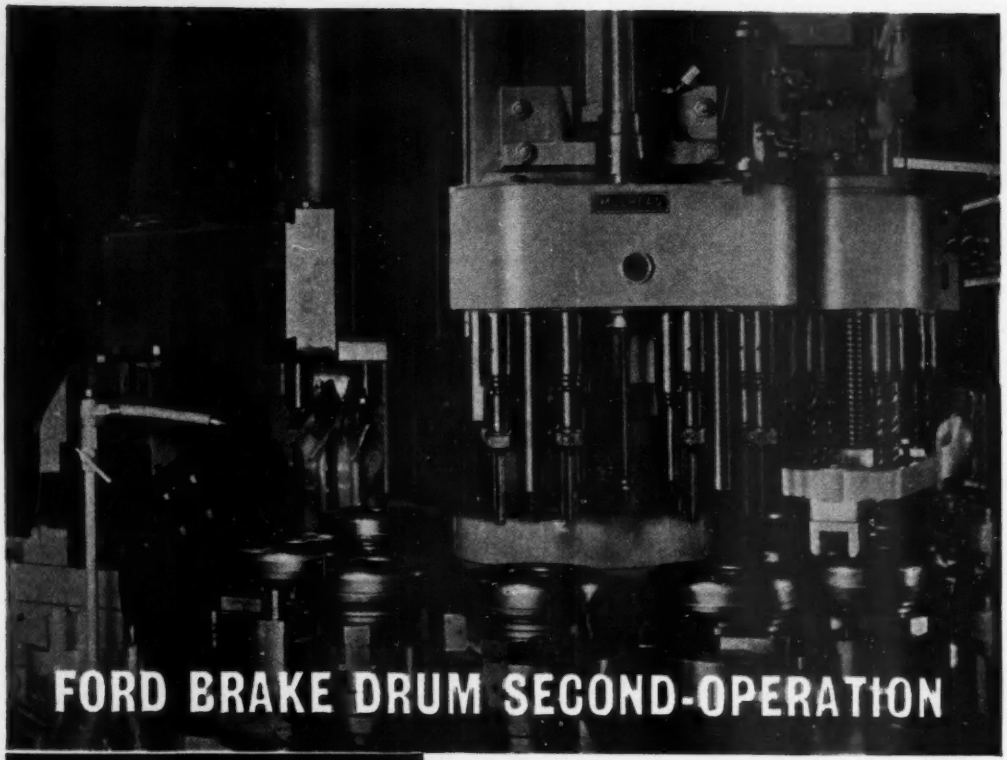

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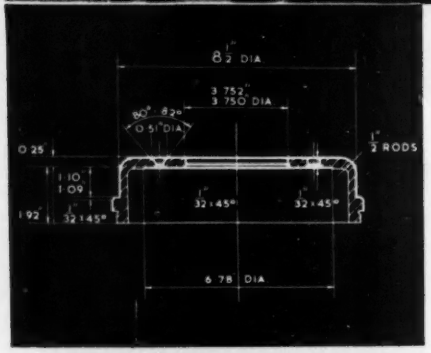

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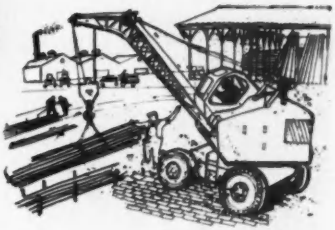

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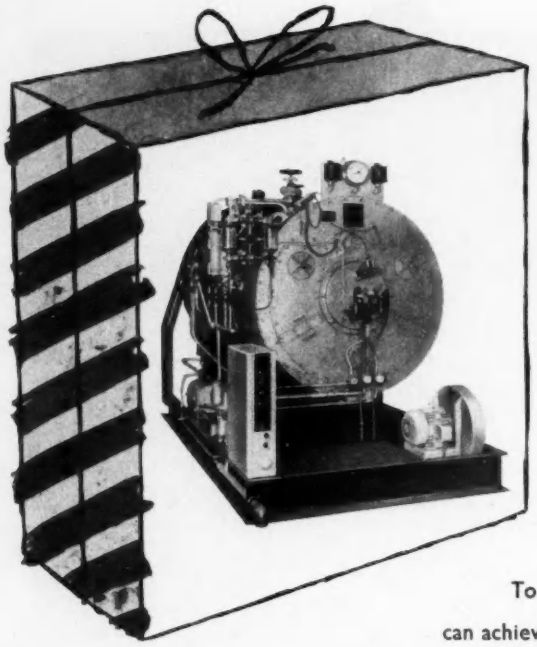

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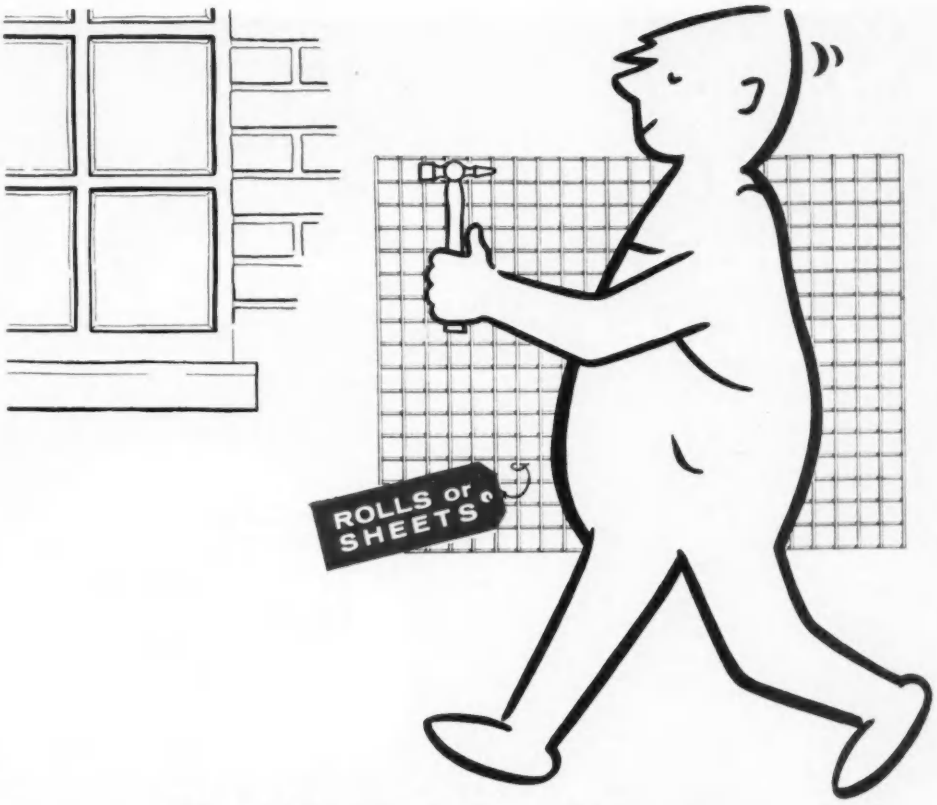

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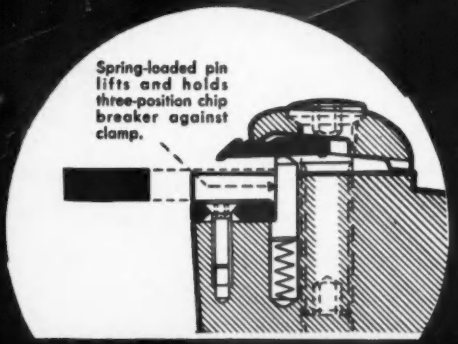

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DESIGNED TO MEET THE REQUIREMENTS
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The illustration shows the Serck Coolers fitted to the Crossley-Laurence Scott 635 KVA alternator sets recently installed in the main pumping stations at the Southern and South Essex Waterworks Companies.

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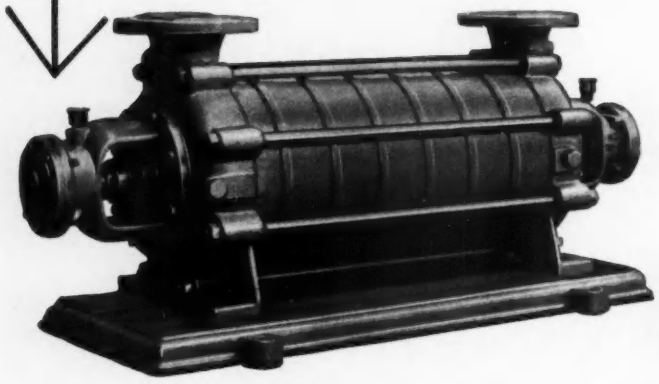

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Closer tolerances, greater precision and better materials mean that you use less power for the same performance, cut internal losses and save on maintenance. If your requirements call for a pump in this special category, let us send you a design and estimate. We can handle any enquiry for pumps ranging from approximately 20 to 1,000 gallons per minute at pressures up to 150 lb. sq. in.

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Angus Gear Units are designed and built to meet the most complex problems presented by modern industrial applications. This service of specialised design is ready to help you at any time. On request a representative will call for on-the-spot discussions, and the resources of Angus designers and technicians—and of one of the most advanced gear cutting plants in Europe—will immediately be placed at your disposal.

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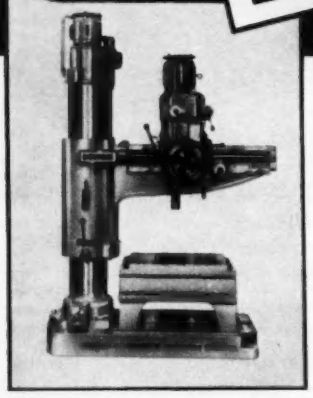

Illustrated above is the H.B. 3/12 Richmond Radial Drilling machine selected by Ingersoll-Rand Company Limited, Compressed Air Engineers, from the extensive range of "RICHMOND" Milling and Drilling machines. Built from the finest materials and incorporating first-class workmanship, all "RICHMOND" machine tools are simple to set up, easy to adjust and combine high productivity with exceptional accuracy.

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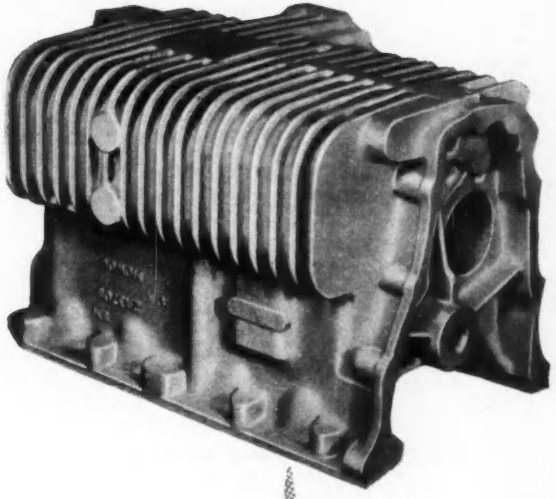

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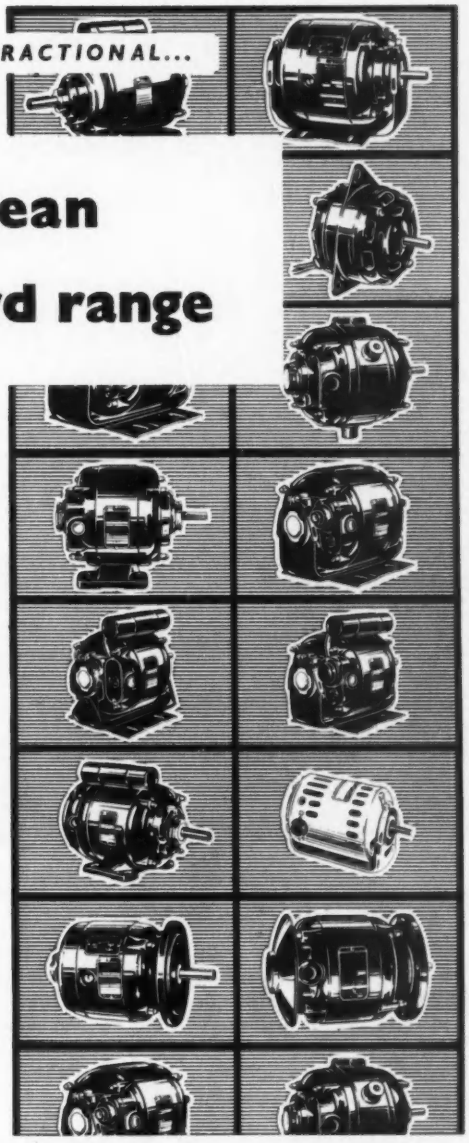

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AEI fractional horse-power motors are made in a wide range—a wide range of mountings, a range of different enclosures and fittings, and a range of special-purpose types of which those illustrated form only a small selection. There is virtually a standard motor for any job. They are made in sizes from one-thousandth horse-power. There are base mountings or cradle mountings; spigot, resilient, ring or automatic tension mountings; horizontal, vertical and 'any-angle-you-want' mountings. There are AC motors, DC motors; geared units, auto-belt tension units; flame-proof or drip-proof enclosures; for high, low or medium speed applications at all standard voltages. Designers of machinery therefore have not only the widest field of choice but can take full advantage of standardisation and interchangeability.

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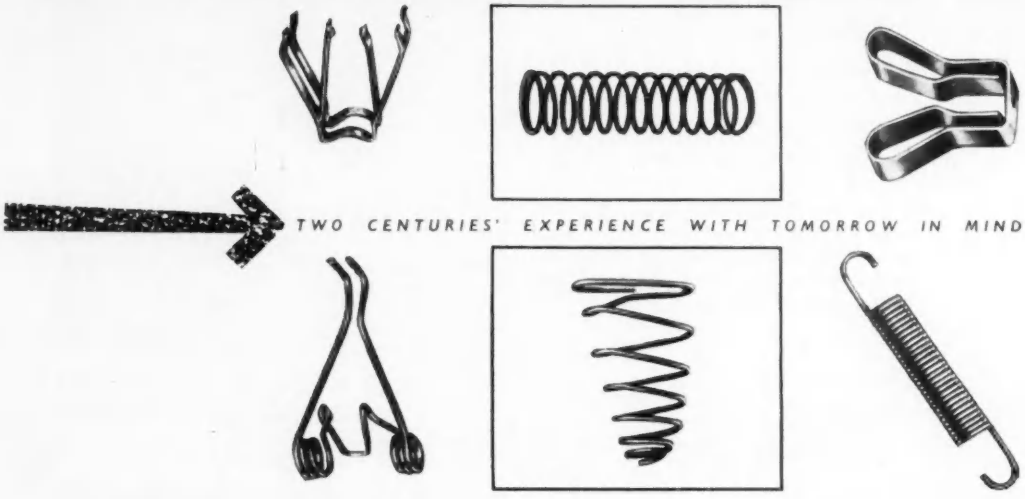

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... Just a turn of the screw

corrects belt tension *while the motor is running with*

KENYON
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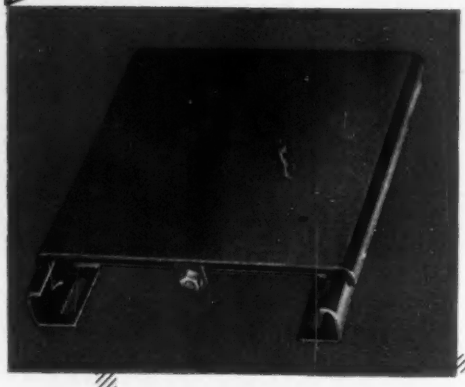

This all-steel motor base will replace slide rails and provide belt adjustments to fine limits ***without stopping the motor.*** It is robust and virtually fool-proof, consisting of a rolled section fixed base and a sliding plate to which the motor is fastened. The motor can be moved through an infinite number of rigid positions by means of a single adjusting screw. Our catalogue 59/4 PT explains ADJUSTO-SLIDE MOTOR BASES fully. Please write for a copy.

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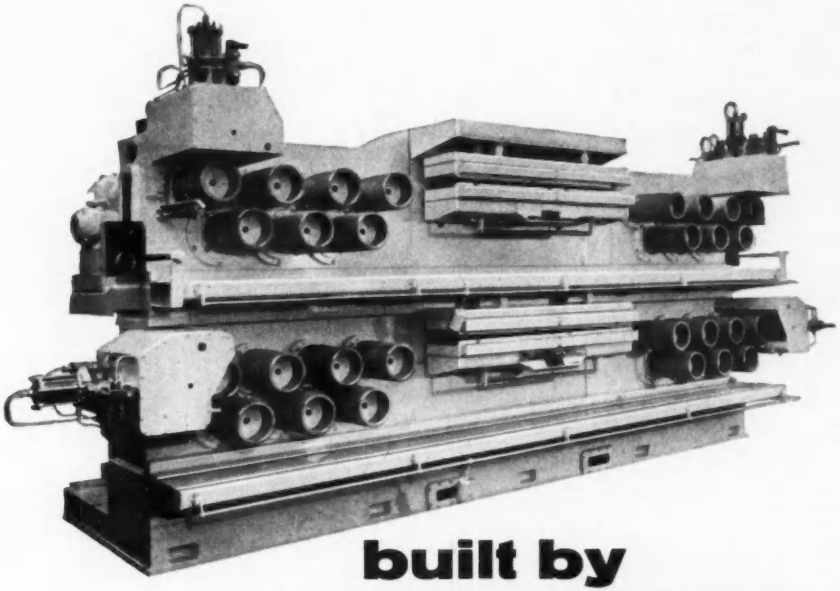

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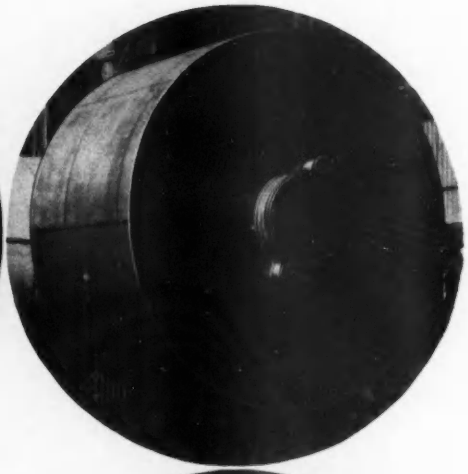

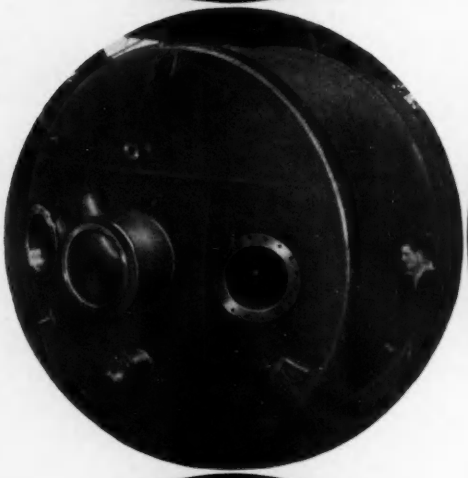

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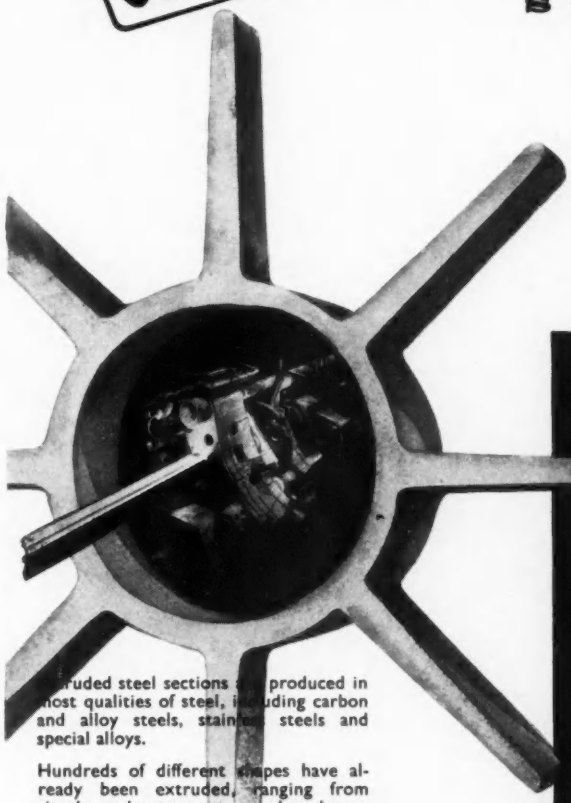
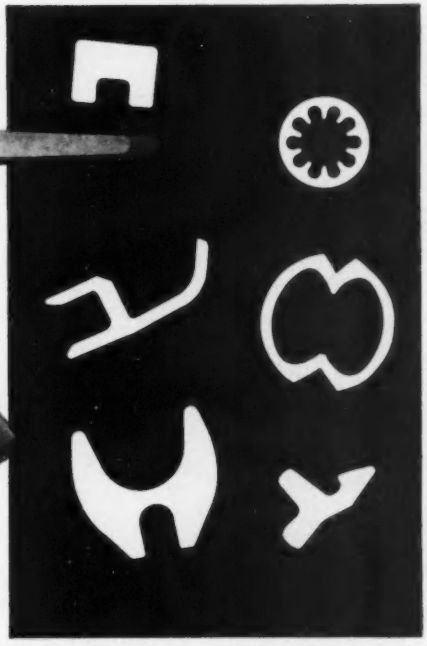
Cut Costs





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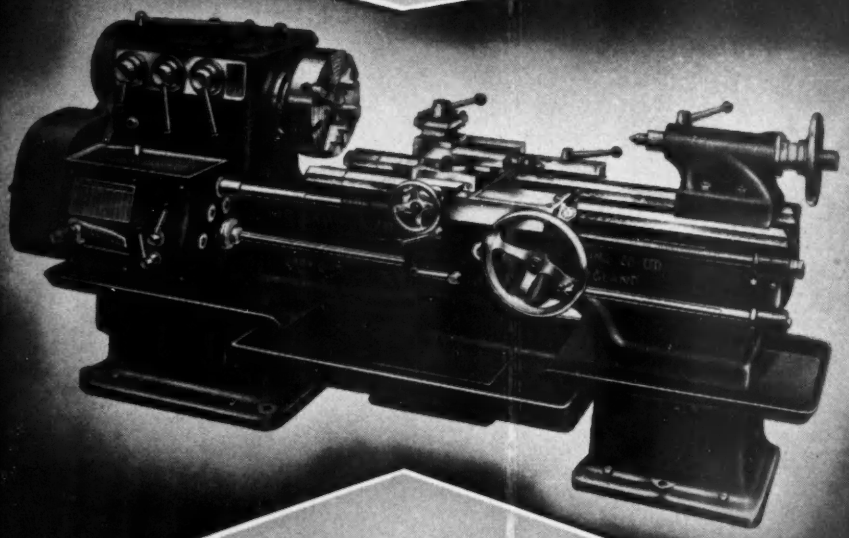

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Recent improvements to the 'Crowthorn' 7½" and 8½" Centre Lathes include:—

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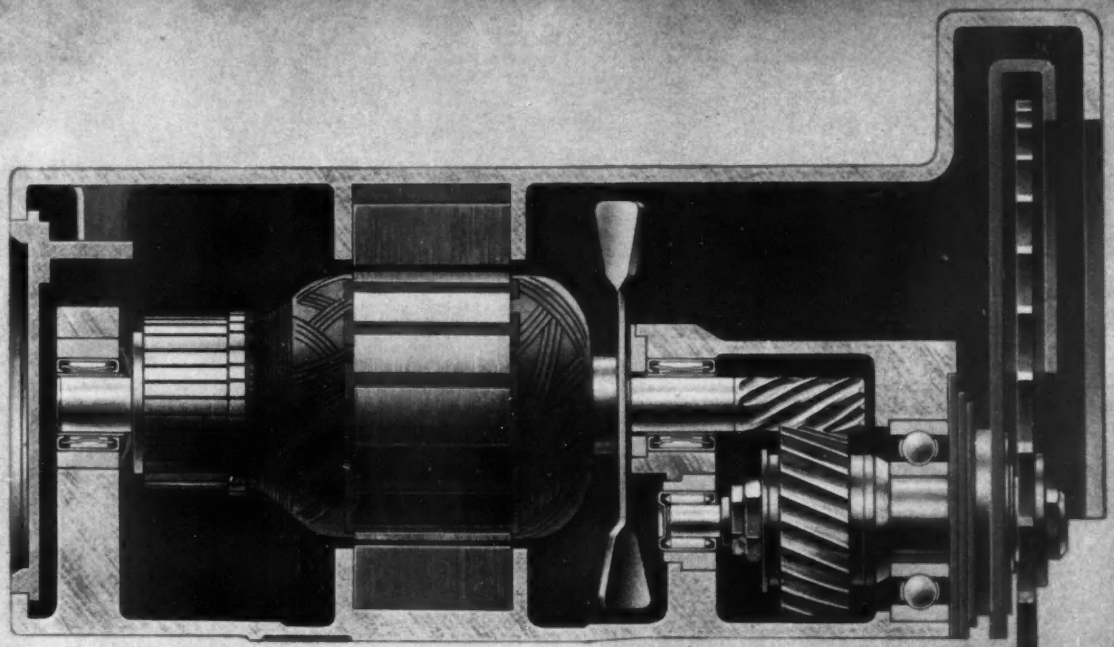

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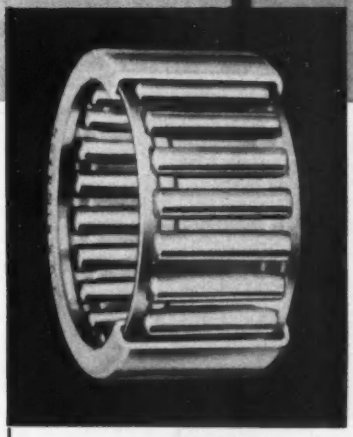
Armatures of many portable power tools are now equipped with Torrington Drawn Cup Roller Bearings, which provide high speed operation and long pre-greased life at low cost. Offering compactness, light weight, easy installation, smooth starting and cool running, the Drawn Cup Roller Bearing can be economically designed into portable drills, saws, mixers, vacuum cleaners, automotive generators and alternators and many other applications.



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Low unit cost

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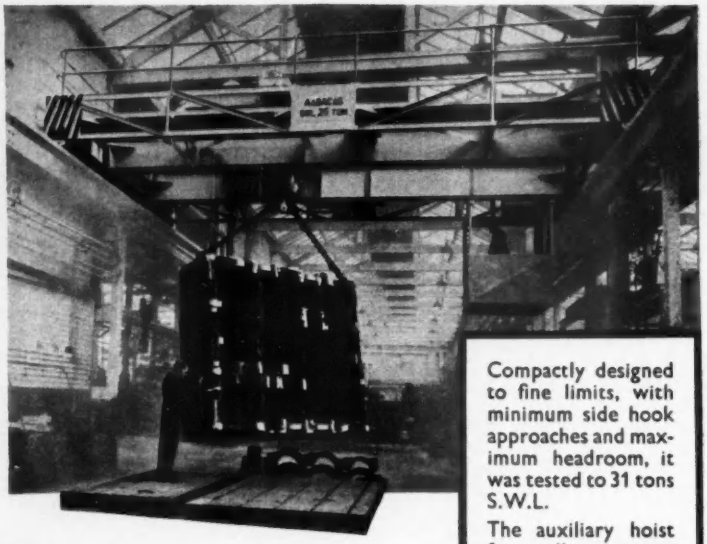

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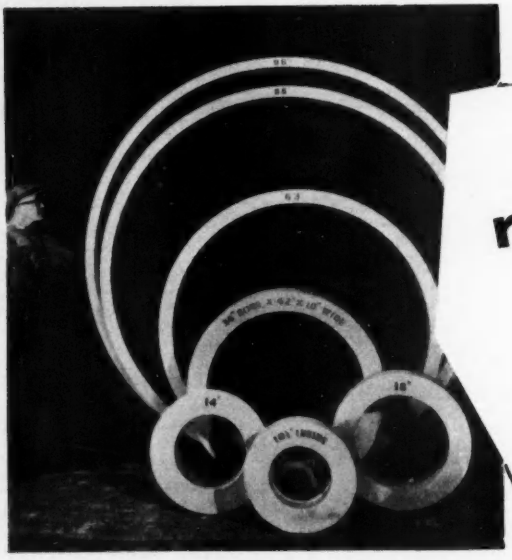

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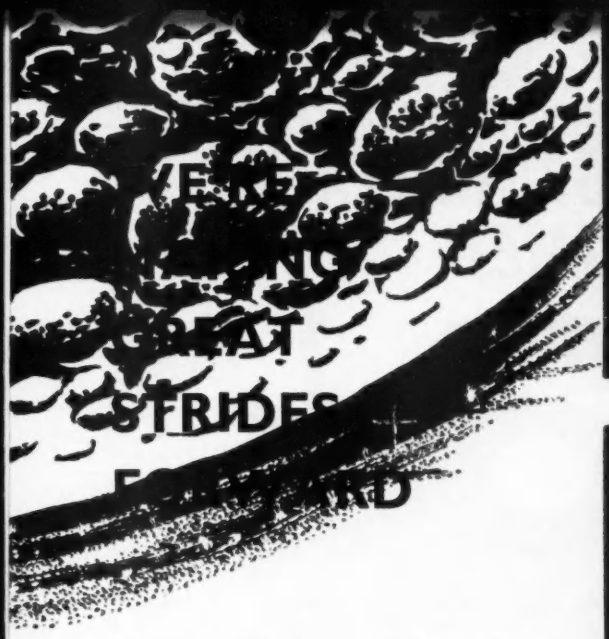

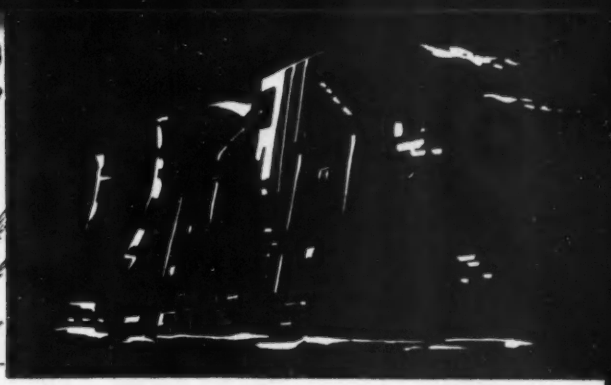

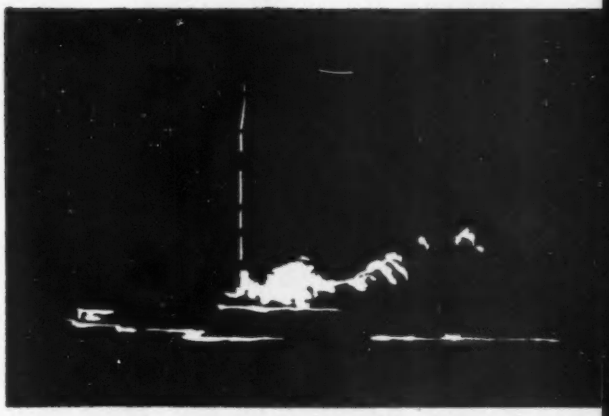

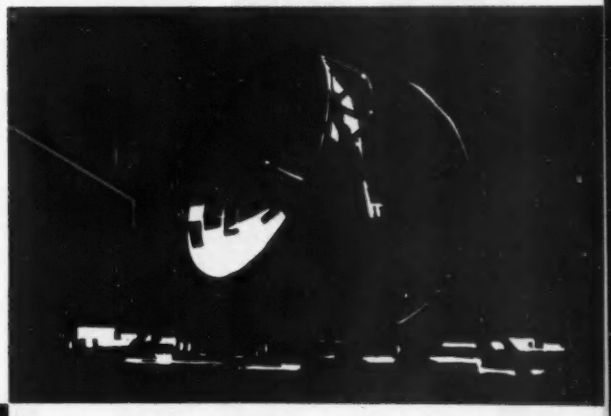

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have brought a challenge—
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MILLION TONS OF OIL
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VARLEY PUMPS

are handling a larger proportion than ever

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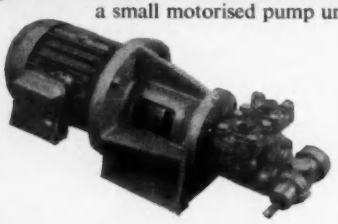

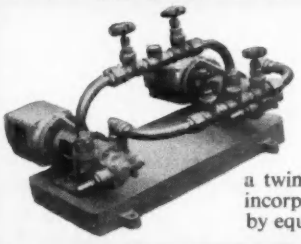

a twin pumping set incorporating stand-by equipment

MOTORISED GEAR PUMPS

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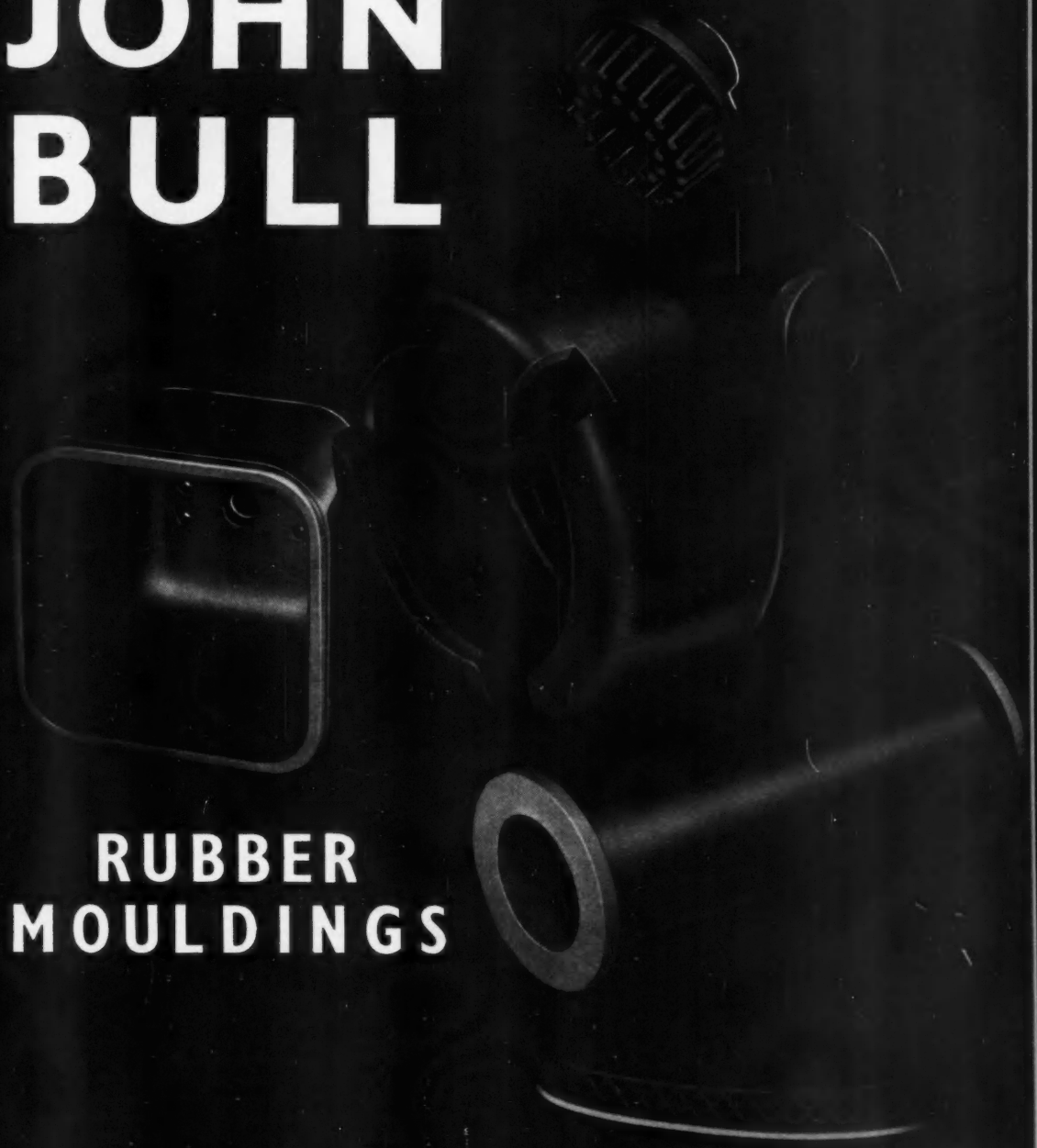

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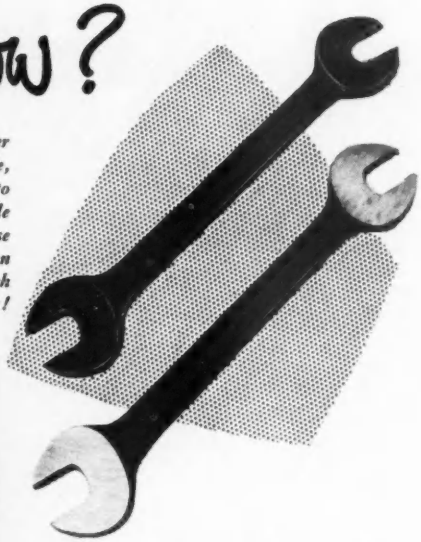

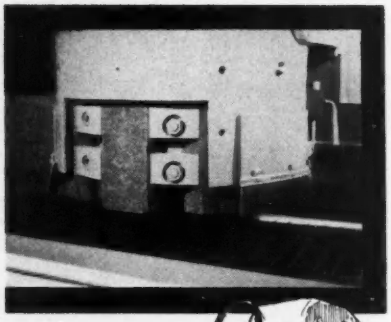

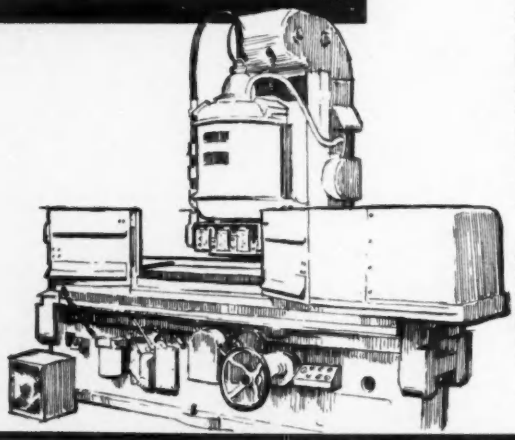

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MATERIAL

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ABRASIVE

Segments AA46 – J5 – VL.

NUMBER GROUND

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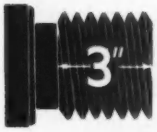
Plunge grind threads 

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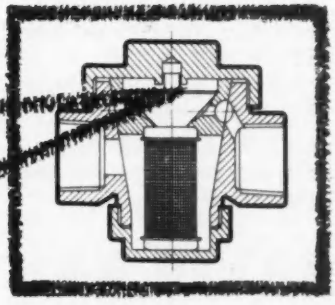

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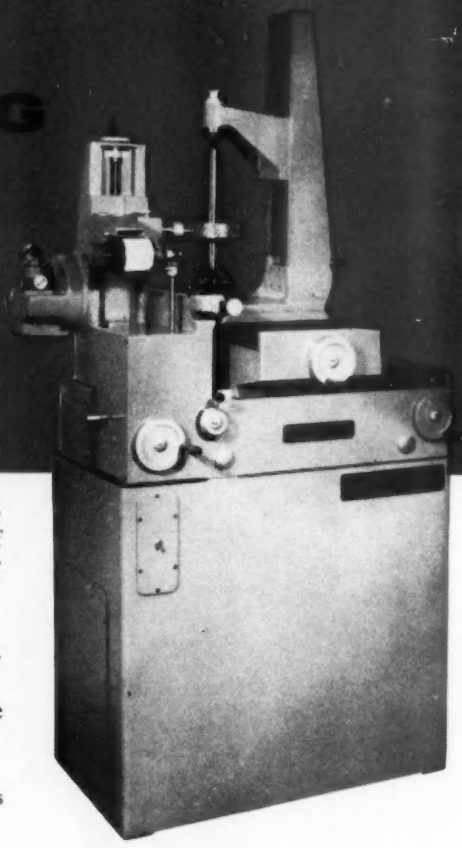

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *COATED-PARTICLE FUELS FOR NUCLEAR REACTORS*

Close attention is now being paid to the possibility of using in nuclear reactors coated-particle fuels, i.e., small spherical particles of fuel, comparable in size with those of common table salt, coated by a vapour-phase process or by fluidized-bed or barrel-plating techniques, with an impervious layer of a ceramic material, e.g., alumina. The thickness of the coating is chosen in such a way that it is not only sufficient to trap all fission recoils within it, but also to ensure that a layer of undamaged material remains to contain fission gases and other fission products. The individually coated fuel particles are evenly dispersed in any suitable matrix material, such as graphite, and the dispersion can then be conveniently and economically shaped into reactor fuel elements of various shapes and sizes by simple mass-production techniques.

One advantage of this type of fuel is that it seems possible under certain conditions to contain fission products almost completely. Fission recoils cannot escape, and diffusion through the ceramic coating is very slow, even at high temperatures; consequently, as long as the coating remains intact, fission-product loss is small. A release of fission products will therefore occur only if there is coating failure. Such a failure will not occur readily, because the coating is strong and the spherical shape is ideal for resisting internal pressure, so that such particles have a high resistance to cracking. Furthermore, thermal stresses are low in the particle coating, as the particles are small. Also, the particles can be made entirely from materials having low cross-sections, so that the neutron economy of the reactor will be good.

From *Nucleonics*, U.S.A., March 1961, pp. 96, 98.

● *IMPROVED FLUX FOR THE SUBMERGED-ARC WELDING OF STAINLESS STEEL*

It is known that stainless steel containing, for example, 18% Cr and 8% Ni can be stabilized against intergranular corrosion by the incorporation of niobium or titanium. For effective stabilization, the content of niobium should be from 8 to 10 times, and that of titanium at least 5 times, the content of carbon. Unfortunately, however, commercially available stainless-steel electrode wire contains insufficient niobium for this purpose in automatic welding operations, bearing in mind the inevitable losses of niobium during welding.

To overcome this difficulty, a new flux for submerged-arc welding has been developed, the weld metal acquiring from the flux a sufficient amount of niobium to stabilize it when the flux is exposed to the heat of the arc. The flux consists of granules of a homogeneous vitreous mass containing 0·5 to 8% by weight of niobium and from 0·2 to 3% of carbon, the niobium (in non-elemental form) and the carbon both being present as indistinguishable and inseparable constituents of the vitreous mass. The flux can be made by mixing niobium oxide, either as such or as the mineral columbite, with the dry powders comprising the other ingredients of the flux, fusing the mixed powders in a furnace lined with carbon, and then pouring the molten material into water. Carbon from the lining of the furnace is absorbed into the flux during its fusion but, if desired, the proportion of carbon in the flux can be increased by including a small amount of anthracite in the powdered ingredients. The main ingredients of the flux can be of any conventional nature, but it is considered preferable to incorporate the niobium oxide in a flux based on calcium silicate, with a proportion of calcium fluoride. Other fluxes such as those based on manganese silicate, can also be used.

From *Brit. Pat. Spec.* 865, 131. Murex Welding Processes Ltd., England.

● *GALLIUM ALLOYS FOR LOW-TEMPERATURE BONDING*

A study has been made of the use of gallium-based alloys as bonding materials. These alloys, which are soft when mixed at room temperature, but resist temperatures as high as 900°C after hardening, appear to have suitable physical and electrical properties for making them useful as bonding materials in electronic devices. Because the heat required in soldering operations is often sufficient to damage delicate electronic components, gallium alloys have been employed to make the necessary connections, and have proved entirely successful. Thus, for instance, the soft alloy can readily be used to fasten wires to various devices, one example of this application being a gold-gallium-tin alloy for attaching thermocouples to power transistors.

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mixing the requisite proportions of liquid gallium, which has a melting point of just under 30°C, and a finely powdered metal. After some minutes of mixing, during which time the gallium "wets" the other metal, the alloy is ready to use. Expansion tests on various gallium alloys have indicated that as much as 10% expansion may occur during hardening. This expansion is not of critical importance, however, as the soft-packed metal will generally compress itself, rather than damage the material in which it is embedded. The addition of aluminium oxide to gallium-gold alloys has resulted in better bonding in cavities of barium titanate, perhaps by reducing the thermal expansion of the mixture. Gallium alloys can also be used to cold-solder various metals, the pieces to be fastened together being positioned with a layer of alloy sandwiched between them, and pressure applied until the alloy has hardened. This process offers the advantage of low-temperature formation and high-temperature strength.

From *NBS Technical News Bulletin*, U.S.A., January 1961, pp. 5–7.

● ***VACUUM METALLIZATION OF HIGH-TENSILE STEEL PARTS***

The coating of steel parts with protective metals, particularly with cadmium, has become a virtual necessity in aircraft construction. These cadmium coatings have been applied exclusively by electroplating but, although electroplated cadmium coatings provide protection, it has been found that the electrolytic deposition of cadmium causes hydrogen embrittlement of the steel and this has become a very serious problem, especially with high-strength steels of 180,000 psi or higher.

According to a recently patented process, the problem of the hydrogen embrittlement of high-tensile steels has been solved by vacuum-metallization techniques for depositing a coating of cadmium on the steel. The process is carried out in a vacuum chamber of suitable size, the high-tensile steel parts being suspended in the chamber and the cadmium vaporized below the parts, so that the vapours flow over and condense on them. The parts are first cleaned, if necessary, but without the use of cathodic cleaning, acid pickling, or any other means involving the release of hydrogen, any scale, grease, oil, or rust being removed by sand-blasting. The sand-blasted parts are then immediately racked in the vacuum chamber, in which a substantially complete vacuum is then drawn. An adequate coating of, for instance, 0·0005 in. of the vaporized cadmium is attained in from 15 to 35 min, the maximum temperature reached by the steel parts during the vacuum-metallization process being about 175°F. After the desired coating has been deposited, the parts are removed from the chamber and are ready for use or for the application of conventional paint or organic coatings, without the need for baking or heat treatment.

From *Brit. Pat. Spec.* 861,892.
Anadite, Incorporated, South Gate, Cal., U.S.A.

● ***SOLID-STATE MODULATORS FOR INFRARED COMMUNICATIONS SYSTEMS***

In conventional radio communications systems, transmission and reception are usually omnidirectional, involving relatively high power requirements, and protection against eavesdropping, where necessary, can be acheived only by complex coding or modulation techniques. Optical communications systems, using modulated radiant energy, overcome some of these disadvantages, as they can be made highly directional to conserve power and to maintain secrecy. Of these, a system based on free-carrier modulation overcomes some of the frequency-response, spectral-transmission, and power limitations inherent in the other systems.

A free-carrier modulator, which depends for its action on a semiconductor phenomenon known as free-carrier absorption, consists of a slab of *n*-type germanium having a *p-n* junction along one face. Radiation from an incandescent source is focused on one end of the modulator, the portion of radiation with wavelengths shorter than that of the absorption edge at 1·7 microns being absorbed at the surface within a depth of 1 micron. The longer infrared wavelengths are transmitted through the material but are attenuated somewhat, depending on the concentration of thermally excited free carriers. If a sinusoidal electrical signal is applied to the *p-n* junction and the voltage swings in the forward direction, i.e., as the *n*-region is made negative with respect to the thin *p*-type layer, holes are injected into the *n*-region from the *p*-region. These injected holes cause the longer wavelengths to be more strongly attenuated than they were previously, and transmitted radiation intensity is reduced, thus modulating the amplitude of the transmitted intensity.

From *Electronics*, U.S.A., March 10, 1961, pp. 177–181.

● ***SINTERED-ALUMINA CUTTING TOOLS WITH INCREASED WEAR RESISTANCE***

The resistance of sintered-alumina cutting tools to both flank wear and cratering is not very good. In this connection, it has been discovered that, for good resistance to flank wear, the grain size of the alumina in the sintered material should be as small as possible; at the same time, for good resistance to cratering, the grains should be well bonded together by the

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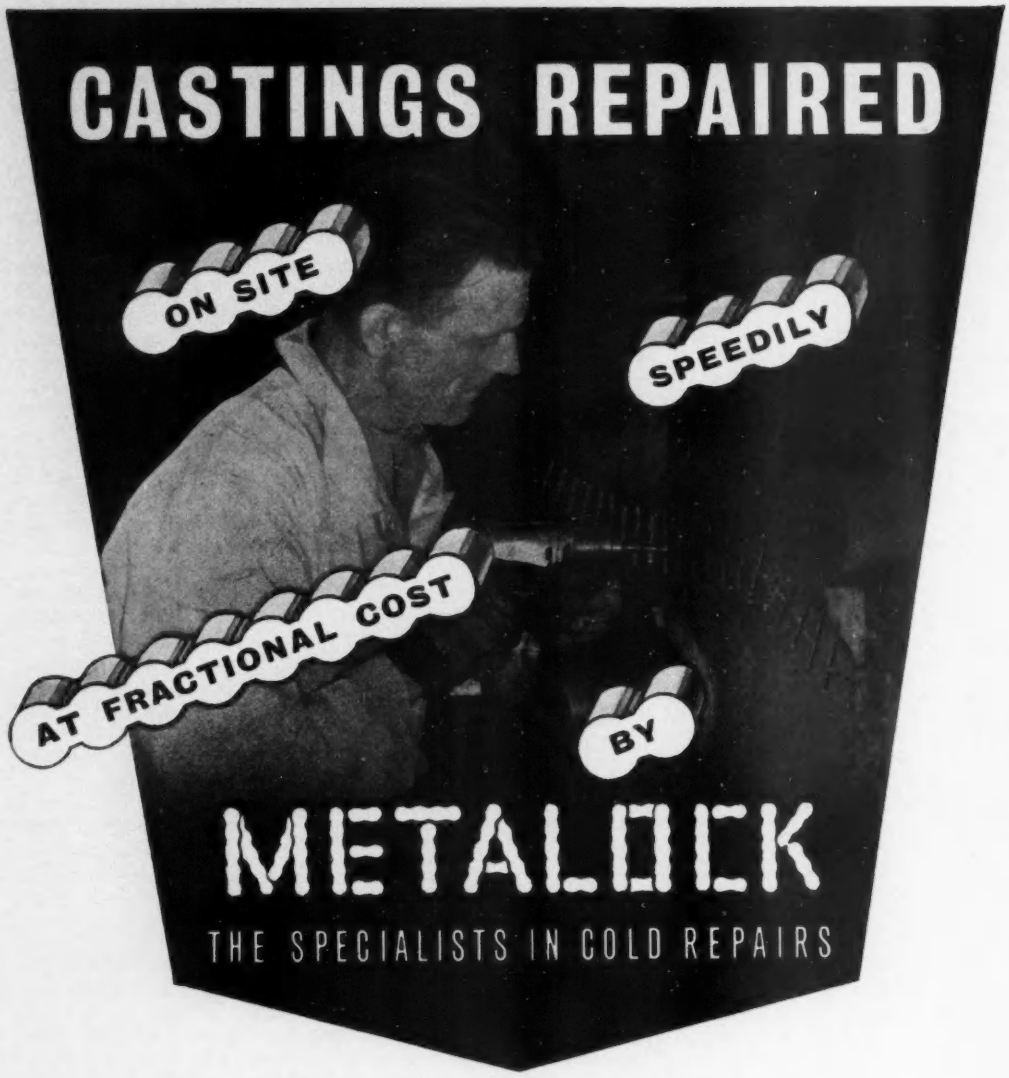

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other materials present. The problem is complicated by the fact that, for good bonding, a high sintering temperature is normally necessary, but high sintering temperatures tend to increase grain size.

It is now reported, however, that these difficulties have been overcome by the development of a new bonding agent which makes it possible to produce sintered materials consisting mainly of alumina, in which both the resistance to flank wear and to cratering are good. Essentially, the material is made by sintering a homogeneous mixture containing from 87 to 96% by weight of alumina and at least 2% of titanium nitride and at least 2% of sub-oxide of titanium (a compound of titanium and oxygen, with or without carbon, the titanium atoms being arranged in a face-centred cubic lattice). Sintering temperatures should preferably lie in the range between 1650 and 1750°C, these temperatures being correlated with the composition of the mixture. Thus, sintering temperature decreases with increasing amounts of sub-oxide of titanium, but increases with increasing amounts of titanium nitride. When the sub-oxide of titanium contains carbon, the sintering temperature should be higher (by up to 50°C) than for the same amount of sub-oxide without carbon. As, however, sintering temperatures cannot be controlled in practice with the desired precision and as the use of a sub-oxide of titanium containing carbon allows greater latitude in the temperature required to obtain optimum results, the preferred composition is one containing 91% alumina, 3% titanium nitride, and 6% sub-oxide of titanium (with 6·7% carbon), the corresponding sintering temperature being 1700°C.

From *Brit. Pat. Spec.* 865,166.
Hard Metal Tools Ltd., Coventry, England.

● *LIQUID-HYDROCARBON FUELS WITH INCREASED ELECTRICAL CONDUCTIVITY*

In view of the low electrical conductivity of conventional liquid-hydrocarbon fuels, such as aviation and automotive petrols, kerosene, and aviation turbine fuels, surging movements in a tank or during pumping operations, such as aircraft refuelling, can give rise to the possibility of a build-up of static electricity and the potential hazard of a consequent spark discharge. For this reason, the use of additives to increase conductivity and hence to eliminate the danger of an accumulation of charges of static electricity has been proposed. Unfortunately, however, such conductivity additives usually have undesirable side effects when incorporated in the fuel, particularly insofar as adversely affecting its oxidation stability is concerned.

With the object of increasing electrical conductivity without adversely affecting the fuel, a new formulation has been developed, basically involving adding to the fuel a small proportion of a salt of a metal having an atomic number between 22 and 28 and an aromatic carboxylic acid or an aromatic or alipathic sulphonic acid, together with a small amount of a metal deactivator which is almost entirely a hydrocarbon with an alkylene radical containing from 1 to 4 carbon atoms, e.g., bis (1-acetonylethylidene) ethanediamine. The metal salts serve as conductivity additives, while the deactivator reduces the catalytic effect of the metal salts as oxygen promoters, without impairing their efficiency as conductivity additives.

The metal salt, which is oil-soluble, has a molecular weight of at least 200, a molecular weight of about 2500 being particularly suitable. Especially effective conductivity additives are chromic di-isopropylsalicylate, chromic dioctyl sulphosuccinate, and a chromic salt of dinonylnaphthalene sulphonic acid. Similar salts of other metals, including those of manganese, vanadium, iron, and titanium, can also be used for this purpose, but those of chromium are stated to be especially suitable, as they are not leached out of hydrocarbon solutions by water.

From *Brit. Pat. Spec.* 861,794.
Bataafse Petroleum Maatschappij N.V., The Netherlands.

● *IMPROVED METHOD OF ALUMINIZING FERROUS-METAL PARTS*

Conventional methods of aluminizing metal parts subjected to high thermal stresses during service, with a view to protecting them against subsequent corrosion and scaling, generally involve the provision of a coating of aluminium by dipping or spraying, followed by heat treatment in salt baths. As a result of this heat treatment, the aluminium is diffused into the boundary zone of the base metal, forming at the surface an iron-aluminium alloy with a high resistance to corrosion and scaling.

Because this heat treatment in salt baths has the disadvantage that the parts involved, which are already finished as regards dimensions, are subjected to some distortion and it is generally impossible to carry out subsequent machining operations, an improved method of aluminizing has been developed, in which the use of salt baths is completely eliminated. In the new process, the parts, e.g., inlet and exhaust valves, combustion chambers, and turbine blades, are first provided with a coating of aluminium in the normal way by dipping or spraying. The parts are then heated in an oxidizing atmosphere to forging temperature or higher, so that diffusion of part of the aluminium takes place into the base metal, together with oxidation of the remaining aluminium on the surface to form a layer of aluminium oxide which, as is well known, can withstand very high thermal stresses. To prevent

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this layer from subsequently flaking off, the parts, after heating to forging temperature, are subjected to a forging operation, causing the aluminium oxide to disintegrate and to be impressed into the surface. At the same time, the forging operation can be used to bring the part to its finished shape. It is stated that, as a result of the high proportion of aluminium oxide impressed into the surface, parts treated in this way exhibit a substantially greater resistance to heat and corrosion than those aluminized by conventional processes.

From *Brit. Pat. Spec.* 864, 494.
Alfred Teves KG, Frankfurt/Main, Germany.

●*SIMPLE MECHANISM FOR STOPPING THE SPIN OF ROTATING MASSES*

Although originally developed to stop the spin of a photographic-reconnaissance rocket to permit high-resolution pictures to be taken during flight, a simple mechanism can be applied to other rotating masses, e.g., to stopping a gas-turbine rotor in an emergency. In the case of the rocket, tests have shown that its spin can be "braked" to a dead stop within a fraction of a second, irrespective of its initial rotational speed. In fact, the more rapid is the rate of spin, the quicker is the rotating mass brought to a stop.

The mechanism depends for its action on the change produced in the geometric configuration of a spinning body when two small connected masses are allowed to unwind from it during rotation. This is achieved by two small diametrically opposed weights connected by cords or flexible tapes wound around the rotating mass and provided with a simple release device. When this device is operated, the weights fly outwards, unwinding the cords and transferring the total angular momentum of the spinning mass to the weights, which are automatically jettisoned at the end of the unwinding cycle.

Mathematical analysis shows that the length of cord required to bring the mass to a stop is a function only of the initial mass configuration of the system and, provided that the proper weights and cord lengths have been selected, release of the weights will stop spinning almost instantly. At the same time, tolerances on weights and cord lengths to obtain the desired results are fairly liberal. Furthermore, irrespective of the initial rotational speed, e.g., 1 or 100,000 rpm, the mass is not jerked to a stop, as the braking action is smooth, and there is no rebound. An interesting feature of the mechanism, which can be designed as a completely self-contained automatic unit, is that it can, if required, be adapted to cause the rotating mass to reverse its direction of rotation to a predetermined speed.

From *Product Engineering*, U.S.A., April 3, 1961, pp.56–59.

● *IMPROVING THE IGNITION BEHAVIOUR OF DIESEL ENGINES DURING STARTING*

In diesel engines having a combustion chamber formed in the piston or alternatively in the cylinder-head and in which a rotary motion is imparted to the combustion air, injection nozzles are used to apply the fuel in the form of a thin film on the smooth portion of the combustion-chamber wall. Because the necessary quantity of very finely atomized fuel coming into contact with the combustion air on all sides is not available for initiating ignition, the behaviour of such engines under starting conditions is not as satisfactory as that of diesel engines which operate by atomizing the fuel through the nozzle. To obviate this drawback, means are sometimes incorporated to inject a fine jet of fuel transversely through the combustion chamber, so as to initiate ignition by atomization. There is, however, an objection to this procedure in that there is a risk of the fine spraying aperture of the nozzle becoming blocked with deposits of carbon.

To improve the behaviour of diesel engines under starting conditions, without having to provide a special spraying aperture at the fuel injection nozzle, a recently patented proposal is to provide a recess to interrupt the smooth portion of the combustion-chamber wall at a specific distance from the injection nozzle, as viewed in the direction of movement of the fuel. As a result, the fuel becomes detached from the wall at the edge of the recess and is surrounded on all sides by the combustion air. At the same time, the fuel is subjected to pre-oxidation, so that it ignites as soon as it is carried from the edge of the recess into the free air. In a diesel engine with a spherical combustion chamber in the piston, the recess can, for example, be located in the side wall of the combustion chamber, as viewed in the direction of fuel injection. However, it is also possible to use as a recess the edge of some opening already in existence, e.g., that of an opening through which the combustion air flows into the combustion chamber, such as the opening of the entry duct of a turbulence chamber or a rotary-swirl chamber.

From *Brit. Pat. Spec.* 865, 536.
J. Effenberger, Bingen, Germany.

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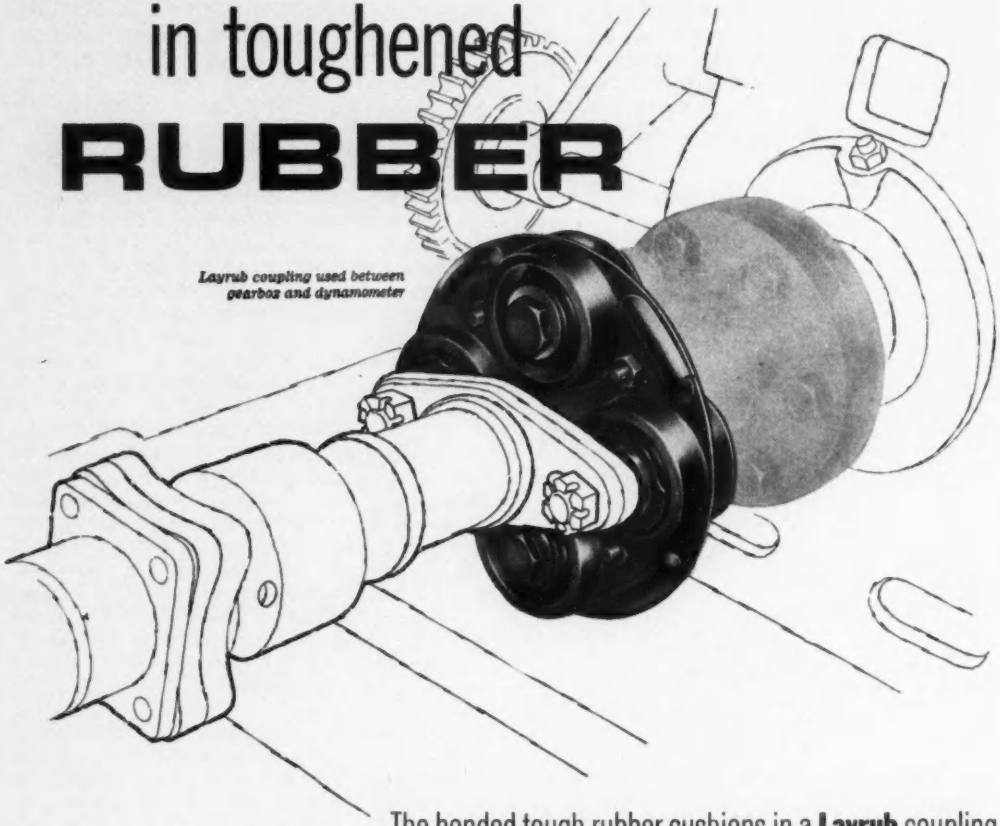

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VOL. XXII No. 5 MAY, 1961

The Use of Nickel Powder for Metallizing

By W. B. KEYSER

From *Welding Journal*, U.S.A.,
Vol. 40, No. 3, March 1961,
pp. 229–231, 5 illustrations.

THE suitability of nickel-plated steel for use in various industrial chemical processes has been well established. During maintenance and modification of process equipment, however, nickel plating is often removed and the exposed metal surfaces become susceptible to chemical attack. A programme was therefore initiated to study the feasibility of applying a corrosion-resistant nickel coating by metallizing techniques.

The advantages of metallizing are that the equipment used is portable, making possible the reclamation of materials in isolated areas, and that the possibility exists of applying a nickel coating over a mild-steel weld which joins two nickel-plated pieces, thus saving the expense of nickel welding filler wire.

One of the most important requirements in protective-coating technology is proper preparation of the surface to which the coating is to be applied. Since it is not practicable to heat the sprayed metal and the base metal in order to fuse the two materials, the base metal must be prepared to bond mechanically with the nickel being applied. Most sprayed metal particles which strike the surface are, however, sufficiently plastic to conform to the irregularities and identations of the surface and thus mechanically to interlock with them.

In tests conducted to investigate the most suitable method of surface preparation, a special portable vacuum-blasting machine was employed, capable of blasting almost anywhere without interfering with associated maintenance. With this machine, the surface of the workpiece is blasted beneath two concentric nozzles surrounded by a brush. Abrasive is directed through the inner nozzle and, the instant the abrasive has done its work, the outer vacuum pick-up nozzle returns it, together with the debris, to a reclaimer. Only compressed air is needed to operate the machine.

Initial blasting tests revealed that the use of aluminium oxide and silica sand in the machine was undesirable, as these two non-metallic materials fractured easily and embedded themselves in the surface of the metal, thus reducing the adherence of the coating.

Several metallic grit sizes were tested. It was found that, for both optimum operational efficiency of the machine and maximum roughness of mild-steel surfaces, a medium-grade crushed chilled-iron blasting grit was the best. The use of larger grit resulted in malfunction of the machine, whereas smaller grit did not roughen the steel surface sufficiently. New, clean grit was used, and precautions were taken to maintain the sharpness of the abrasive. Air pressure at 90 psi was necessary for the maximum efficiency of the machine. It should be noted that oil and water in the blast, as well as worn nozzles and dirty or rusty grit, greatly reduce the bond strength of the sprayed coating.

Until recently, most sprayed metal coatings were applied by feeding a wire into an oxyacetylene flame, an air blast blowing the molten metal particles onto the surface being treated. This type of coating is porous, and its use for resisting corrosion is limited.

Recent commercial developments have made available a special metal-powder spray gun, and this was used in all experiments. Tests conducted to determine the conditions under which a nickel coating of the greatest density could be obtained revealed that hydrogen flow should be 40 cfh, oxygen flow 20 cfh, and air-cooling pressure 50 psi. Furthermore, a ceramic nozzle and a vibrator should be used, the gun being held approximately 4 in. from the work.

Since the spraying of nickel powder is not as yet a commercial process, a nickel powder had to be obtained, which spectrochemical analysis revealed to have the following composition:—99·05% Ni, 0·029% Si, 0·02% Mo, 0·003% Al, 0·09% C, 0·006% S, 0·05% B, 0·09% Cu, 0·05% Cr, 0·02% Mg, and 0·03% Mn. The average particle size was 3·85 μ.

X-ray diffraction analysis of coatings prepared with this powder indicated that it contained approximately 40% metallic nickel, 40% nickel oxide, and a total of 10% β- and γ-nickel hydroxides.

Sprayed metal coatings contract after application. Contraction, in turn, results in the formation of stresses within the coating which may affect the mechanical bond between the coating and the base. As the thickness of the sprayed metal increases, the contracting stresses increase to values greater than the adhesion forces, and cracking of the coating results. Concave and flat surfaces present greater problems, with regard to shrinkage of the coating, than do convex surfaces. Coatings on concave surfaces tend to shrink in a direction which would loosen them. Accordingly, tests were conducted to study the bond strength for flat mild-steel samples and for concave samples with inside radii of not less than 5½ ft. These tests indicated that there is a maximum, as well as a minimum, overlay thickness, i.e., the layer should be at least 0·02 in., but not more than 0·05 in., thick.

A cross-section was cut from test samples for bend tests, the size of the bend samples being $\frac{1}{8} \times \frac{1}{8} \times 2$ in. The sprayed plating started to peel on each of the samples after bending through about 5 deg., thus revealing the relatively low bonding tensile strength of the sprayed nickel-powder coating.

In conclusion, it can be said that metallized nickel powder is applicable for service in industrial chemical processes; to ensure optimum results, however, a close control of all phases of the process is essential.

(*Concluded on page 82*)

Remelting Steel by the Electro-Slag Process

By A. F. Tregubenko, V. G. Speranskii, and S. A. Leibenzon

In this article, details are given of a new electric furnace which has been designed for remelting, beneath a layer of slag, steels produced in standard arc furnaces and which is capable of casting three ingots per heat, each weighing up to 1100 kg. In addition, the results of tests on a number of steels are reported, showing how the new furnace enables their properties to be substantially improved.*

From *Stal*, Russia,
No. 3, 1961,
pp. 233–238, 4 illustrations.

Based on the same principle as an electric furnace which has been in operation since May 1958, a more powerful furnace for remelting, under a layer of molten flux, steels produced in standard arc furnaces and casting the ingots in water-cooled moulds has now been developed in Russia.

The new furnace (Fig. 1) consists of two separate units I and II, each with three moulds, arranged so that the two units operate alternately, metal being melted in one unit while the other is being prepared. The water-cooled copper ingot moulds are designed to produce round ingots of 300 mm diameter, weighing from 700 to 750 kg each, or square ingots (310 × 310 mm), weighing up to 1100 kg. Three ingots, with a total weight of up to 3300 kg, can thus be cast per heat, as compared with only one 360-kg ingot in the original furnace. Water for cooling the mould and stool is supplied by a centrifugal pump at a pressure of from 3·5 to 5 atm, depending on temperature. The copper stool and igniter, which are located at the bottom of the mould, act as the base of the mould. The electrode column, with its clamp and carriage, contains the electrode, which, in this process, is the "charge". Power is supplied to the furnace from a transformer, the current being from 6 to 7 kA at a voltage of 50 V.

It should be understood that the main components of the furnace described above are far from perfect. Thus, the welding operations involved in the production of the water-cooled copper moulds have complicated their manufacture and have made repairs more difficult, as these mould welds must withstand water pressures of up to 5 atm and can be made satisfactorily only by highly qualified gas welders. On the other hand, steel moulds are easy to weld and are much cheaper than designs in copper, which is in short supply. For this reason, steel moulds for round ingots, made from seamless tube, as well as steel moulds of square cross-section, cooled by water running freely down their walls, are now being produced.

Another disadvantage is that the method used for electrical contact is inadequate, resulting in the possibility of the stool rapidly becoming unsatisfactory, while melting of the igniter may cause incorrect chemical composition of the ingot in the region concerned. Centring of the long electrode during a melt is also associated with considerable difficulties, as heating of various parts of the unit comprising the electrode column and carriage can cause the electrode to be located eccentrically with respect to the mould axis, with disturbance of the thermal conditions for crystallization of the ingot.

To overcome these drawbacks, a new design of stool has now been developed and adopted, in which the upper slab is made of copper and the remainder of steel, the two parts being connected together by studs. The conductor used in the new stool is connected directly to the slab and thus provides reliable contact between the stool and igniter. In this way, any possibility of damage to stools caused with the old design by arcing between the stool and igniter has been eliminated. In addition, the new stool does not have a central aperture for the igniter, making it unnecessary to provide a stud and nut for each ingot cast. An even simpler design of stool is at present under development.

To cast an ingot weighing 700 kg, the consumable electrode, about 180 mm in diameter, must be from 3·5 to 3·6 metres in length and must be of one-piece construction, as any weld in the electrode might, when melted, form a contaminating crust in the ingot. To enable electrodes of such accurate lengths to be clamped, their top ends are welded to pieces of another metal, by means of which the electrodes are clamped to the carriage.

Two types of flux are used, i.e., (1) the electro-slag process flux (generally of a type containing about 65% CaF_2, from 30 to 35% Al_2O_3, and from 3 to 6% CaO, with a combined total of not more than 1% MgO, SiO_2, and FeO), and (2) a flux which is electrically conductive in the solid state for initiating the electro-slag process. A mixture of aluminium and magnesium powder and the electro-slag flux can be used for this purpose.

When preparing for melting, the igniter is first fixed to the copper stool and about 400 grams of the electrically conductive flux is poured onto the igniter. The stool is then brought tightly up against the lower edge of the mould wall, the electrode is lowered until it comes into contact with the electrically conductive flux, and the electro-slag flux (23 kg in the case of a mould for a 700-kg ingot) is poured into the gap between the inner wall of the mould and the electrode. The current is then switched on and is initially regulated manually from ammeter readings. The process usually becomes stabilized in between 10 and 15 min, after which it is switched to automatic control. The melting process is usually quiescent. If, as is sometimes the case, the discharged cooling water becomes heated above the specified limit (60°C), all that is necessary is to reduce the power input slightly. Possible turbulence (or even splashing) of the slag may occur if the slag bath is not deep enough, in which case its depth should be increased. However, if the amount is excessive, the surface of the ingot may be unsatisfactory.

The process of casting the 700-kg ingots takes from 3 hours to 3 hr 20 min. To stop the process, the electrode feed mechanism is first switched off. For a short time, the tip of the electrode, still immersed in the slag, continues to melt, the current gradually decreasing until finally there is an arc discharge between the end of the electrode and the surface of the slag, after which the electrode is raised and the current is switched off. At the conclusion of melting, the metal and slag are allowed to

* This abstract is based on a full translation received from the Iron and Steel Institute, London. The full translation will appear in *Stal in English* No. 3, to be published by the Institute on June 26, 1961.

cool for a predetermined period, the stool and igniter are then lowered, the ingot and slag are broken away from the walls of the mould, and the ingot is withdrawn. Finally, the ingot is moved to one side by turning the column of the withdrawal mechanism and is transported by a travelling crane. When the ingot is removed from the mould, its temperature is not uniform, the bottom part being dark and the upper part at a temperature of about 1000°C. Subsequent cooling conditions of the ingot depend on the grade of steel involved.

As an example of the economics of the process, it may be mentioned that, in the production of ingots of from 700 to 720 kg, this furnace had an output during 1959 of 460 kg/hr (allowing for time spent in preparing for melting). To achieve this output, the specific power consumption was 1250 kWh/ton, the specific consumption of electrodes 1·02 tons/ton, the specific consumption of the electro-slag process flux 35 kg/ton, and the specific consumption of water 240,000 litres/ton.

Effects of Electro-Slag Remelting on Various Metals

Investigations have been made into the effects of electro-slag remelting on the properties of a number of steels, including ball-bearing steel, stainless steel, austenitic alloy steel, constructional steel, and other steels.

The most important results of these investigations are as follows:—

Ball-Bearing Steel

The most important characteristics of ball-bearing steel are its macrostructure and its content of non-metallic inclusions. The results of tests on two chromium steels for ball bearings showed that their macrostructure was substantially improved by electro-slag remelting and that there was practically no porosity, either axial or overall, after remelting. Also, the content of non-metallic inclusions, particularly oxides, was considerably reduced, compared with the content in metal from standard arc-furnace heats, while the string form of these inclusions was practically eliminated. Furthermore, the location of the inclusions throughout the metal was improved. Thus, their distribution was more or less uniform over the whole cross-section, instead of being in the form of large isolated accumulations, making them less detrimental. The total content of oxide inclusions was from 50 to 66% lower after electro-slag remelting, their chemical composition remaining practically the same.

Research directed towards improving the quality of ball-bearing steels has shown that the composition of the electro-slag process flux has a marked effect on the development of oxidation processes and on the degree to which the metal is desulphurized. In fact, comparative tests on melts of one of these ball-bearing steels carried out with normal fluxes and remelted with unsatisfactory fluxes containing large amounts of silicon dioxide and reduced amounts of aluminium oxide showed that the use of unsatisfactory fluxes produced a substantial increase in the content of oxides and sulphides. The purity of the fluxes used must therefore be recognized as one of the basic conditions essential for producing high-grade electro-slag steel.

Stainless Steel

Tests carried out on a chrome-nickel stainless steel containing titanium showed that, when this steel was remelted in the electro-slag furnace, the losses in titanium content in the lower part of the ingot were as high as 70 to 90% and in the upper part up to 60%. The reasons for this high loss of titanium are directly attributable to the effects of the oxidizing capacities of fluxes containing oxides which are easily reducible by titanium, e.g., SiO_2, FeO, and MnO, and also to the transfer of oxygen from the air through the molten slag into the metal during melting.

For this reason, tests have recently been conducted with this stainless steel, using a flux of pure calcium fluoride, with the slag bath shielded in argon supplied via a tube inserted through an aperture in a graphite

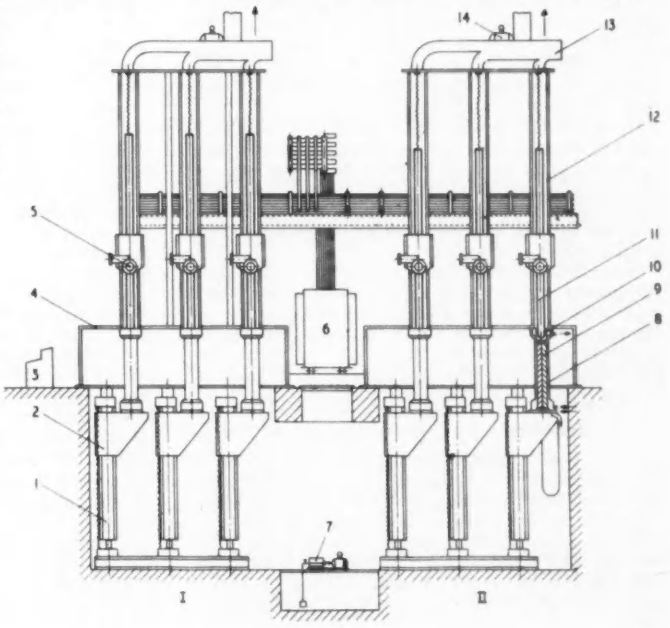

Fig. 1. Schematic arrangement of the new electro-slag furnace for remelting steel.
(1) Rotatable column.
(2) Carriage.
(3) Control panel.
(4) Pedestal.
(5) Bar-clamping mechanism.
(6) Transformer.
(7) Water pump.
(8) Ingot mould.
(9) Remelted metal.
(10) Slag bath.
(11) Bar being melted.
(12) Electrode column.
(13) Suction system.
(14) Fan drive.

mould cover, another aperture in the centre of the cover being provided for the passage of the electrode. It was found that the use of pure calcium fluoride greatly reduced the loss of titanium, and ensured that it was evenly distributed throughout the entire length of the ingot. The method of shielding used was, however, effective only with ingots of not more than 250 mm in diameter.

If the titanium content of this stainless steel is not to be reduced by the electro-slag process, it is essential that there should be no scale, rust, or oil on the surface of the electrodes, which should therefore be pickled or carefully cleaned with an emery wheel prior to remelting. Although electro-slag remelting causes a decrease in the sulphur content of this steel (this is also generally the case with other steels) by about 40%, it hardly alters the contents of the other elements, i.e., carbon, chromium, nickel, manganese, silicon, and phosphorus.

Since the ingots are cast in water-cooled moulds, they do not have the surface defects associated with teeming. Their macrostructure is excellent and their surface finish is so good that they can be sent for further processing without the need for chipping.

Another advantage of the electro-slag remelting process is that nitride inclusions are much finer and, as in the case of other inclusions, their distribution is uniform over the entire cross-section, i.e., there are no accumulations. The ferrite-phase inclusions also become considerably smaller after electro-slag remelting. Practically no alpha-phase inclusions are found, and the uniform distribution of this phase over the cross-section greatly improves the pierceability of tube stock made from this stainless steel. The mechanical properties of the electro-slag steel are practically the same as those of the steel melted in arc furnaces.

Austenitic Alloy Steel

Preliminary tests on a high-alloy austenitic steel containing aluminium and titanium showed that electro-slag remelting caused losses in titanium content of from 10 to 20% and in aluminium content of from 10 to 30%. The contents of the other elements, with the exception of sulphur, which was reduced by from 20 to 50%, were hardly altered. It was found, however, that the use of the electro-slag process flux previously mentioned enabled titanium losses to be greatly reduced, while those of aluminium became small, this being achieved without the protective measures used when remelting the stainless steel, as already indicated, i.e., a flux of chemically pure calcium fluoride, an argon-shielded slag bath, and a graphite mould cover.

Electro-slag remelting reduced the hydrogen content of ingots of this high-alloy austenitic steel from a maximum of 10 cm^3/100 gm to a maximum of 6 cm^3/100 gm. The structure of the steel became dense, with the ferrite component uniformly distributed, i.e., without coarse accumulations. Also, the plastic properties of the steel in the hot state were considerably improved.

Constructional Steel

When steel is remelted by the electro-slag process in water-cooled moulds, the amount of non-metallic inclusions is substantially reduced, while the manner in which they are distributed changes. The saturation of the metal with gases, particularly hydrogen, also decreases. For instance, when metal from one heat was remelted in the electro-slag furnace, the hydrogen content decreased from 10·3 to about 6 cm^3/100 gm, while in another heat it decreased from 8·2 to about 5·2 cm^3/100 gm. The nitrogen content remains virtually unchanged.

In the case of one Russian constructional steel containing chromium, nickel, and tungsten, it is known that, when this steel is produced in arc furnaces, fractures often reveal defects, while its mechanical properties, especially its impact strength, are not sufficiently high, anisotropy being considerable. On the other hand, tests have shown that, when this steel is subjected to electro-slag remelting, it becomes sounder, and fractures do not reveal defects. Practically no internal hairline cracks are found in specimens of this steel during the removal of successive thin layers. It should also be noted that the improvement in mechanical properties is very good.

In the case of another Russian constructional steel containing chromium and molybdenum, it is known that its main defect is the presence of spot segregations in the macrostructure. In electro-slag ingots of this steel, however, practically no segregations can be observed, and the fact that the non-metallic inclusions are well dispersed prevents the occurrence of spot segregation when this steel has been remelted.

Other Steels

When typical high-speed steels are remelted in the electro-slag furnace, their chemical composition remains almost unchanged, with the exception of their sulphur content, which decreases greatly.

The ingots produced must be despatched for annealing as soon as they are removed from the moulds, in order to prevent a marked reduction in the output of sound forgings, as ingots tend to crack when heated for forging, if thermal stresses present in them have not been relieved. The macrostructure of electro-slag high-speed steel is notable for its high density and homogeneity. Remelting reduces the content of non-metallic inclusions, and their distribution becomes more uniform.

Similarly, a reduction in the total amount of non-metallic inclusions, such as oxides and sulphides, from 0·035% in the initial metal to 0·010% in the electro-slag metal, together with their more uniform distribution, improves the normally very poor ductility in the hot state of one Russian steel containing 28% chromium. In addition, the manner in which the ingots crystallize as a result of rapid cooling in the water-cooled moulds improves the macrostructure and hence the plastic properties in the hot state of this steel.

Coarse hairline cracks are often found in another Russian steel containing 0·2% carbon and 13% chromium —a defect which cannot be tolerated in turbine-blade applications. However, there were grounds for believing that electro-slag remelting would be conducive to bringing about a considerable reduction in the content of non-metallic inclusions in this steel and to eliminating string patterns of inclusions, with a consequent improvement in the quality of the metal insofar as the tendency to hairline cracking was concerned. To confirm this belief, tests were carried out on twelve electro-slag ingots of this steel. It was found that these ingots had no pores, cracks, or coarse defects of segregation origin, as distinct from the initial metal, which contained these defects. In addition, there was a reduction of from 50 to 66% in the content of non-metallic inclusions, such as oxides and sulphides and their distribution along and across the ingots was more uniform, with no string formations and no signs of hairline cracks. As a result, it is concluded that electro-slag steel of this type is definitely suitable for use in the manufacture of turbine blades.

Spring-Force Accumulators for Quick-Acting Switchgear

By P. BRÜCKNER and A. ERK

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EXTRA-HIGH-SPEED circuit breakers are used to limit and switch out high short-circuit currents in low-voltage installations, and quick-acting closing devices are used to shunt and by-pass vulnerable equipment that might otherwise be damaged by short-circuit currents or large over-currents. In these quick-acting units, contact acceleration requires very rapid release mechanisms for the forces actuating the contacts, these forces usually being stored in spring systems. It is therefore the purpose of this article to investigate various types of spring arrangements as regards their suitability for high-speed switching operations.

In order to switch out short-circuit currents before they reach their peak value, actuating times must be short. Thus, it is necessary to have high spring forces and to keep the masses of the contact elements as small as possible. The size of these masses depends on the nominal current rating of the apparatus and the design features of the spring system. The four main types of springs used are tension-bar springs, torsion-bar springs, helical springs, and disc springs (Belleville springs), as shown in Fig. 1. These four types give high values of stiffness without much inherent spring mass, so that they have high natural frequencies, permitting them to operate with correspondingly short actuating times.

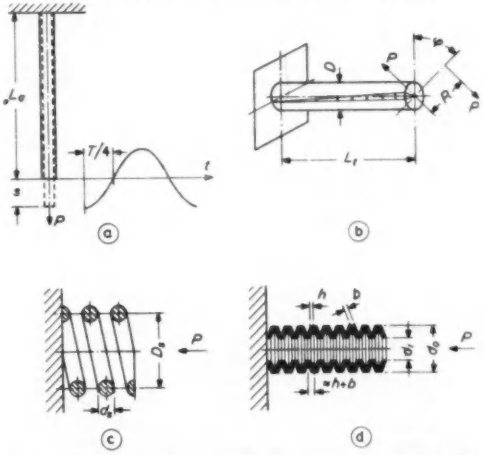

Fig. 1. The four main types of springs used in quick-acting switchgear, showing (a) a tension-bar spring, (b) a torsion-bar spring, (c) a helical spring, and (d) Belleville springs.

In the following, the natural frequencies of these four spring types will be calculated with and without the additional mass of the contacts, and the actuating times obtainable will be compared. A simple procedure for the rapid determination of spring frequencies will also be developed.

Natural Frequency of Springs without Added Masses

When a spring clamped at one end is deflected through a distance s and then suddenly released, it will vibrate at its natural frequency f. The time t_s required to cover the distance s after sudden release is one-quarter of the natural period of vibration T of the spring. In spring-actuated switchgear, only this first quarter-cycle of the vibration is of importance, since it is during this time t_s that the contact pieces move from one extreme position to the other. The distance a travelled by the contacts can be equal to the distance s, smaller than s if the spring is not fully relieved of its load, or greater than s if lever ratios are used.

A tension-bar spring of length L_a subjected to an axial load P which is suddenly released vibrates longitudinally at a natural frequency f_a, denoted by

$$f_a = (1/4L_a)\sqrt{Eg/w} \text{ [cps]} \quad .. \quad .. \quad .. \quad (1)$$

where E is the modulus of elasticity [psi] and w is the density of the spring material [lb/cu in.]. Usually, the extension s is specified, and the material can be used up to its maximum permissible value of axial stress σ_a. The length L_a of the bar is then determined from

$$L_a = Es/\sigma_a \text{ [in.]} \quad .. \quad .. \quad .. \quad .. \quad (2)$$

Full utilization of the spring material up to the stress limit σ_a ensures that the bar will reach its highest possible fundamental frequency, i.e.,

$$f_a = \frac{\sigma_a}{4E}\sqrt{\frac{Gg}{w}} \times \frac{1}{s} = \frac{C_1}{s} \quad .. \quad .. \quad .. \quad (3)$$

In the case of a torsion-bar spring, a plain cylindrical bar of length L_t and diameter D is clamped at one end and is subjected at the other end to a torque due to the action of a force P acting on a lever-arm of radius R. After sudden release, the bar vibrates in torsion. If τ_t is the permissible shear stress of the material, and s is the transverse distance corresponding to the angular displacement, the length of the bar will be given by

$$L_t = GDs/2R\tau_t \quad .. \quad .. \quad .. \quad .. \quad (4)$$

where G is the modulus of rigidity [psi]. The fundamental frequency of the torsion bar is given by eq. (1), if L_a is replaced by L_t and E by G. For ease of comparison between the various spring types, it is convenient to make $R = D/2$, so that the natural frequency of the torsion bar can be obtained from

$$f_t = \frac{\tau_t}{4G}\sqrt{\frac{Gg}{w}} \times \frac{1}{s} = \frac{C_2}{s} \quad .. \quad .. \quad .. \quad (5)$$

A somewhat more detailed treatment is necessary in the case of a cylindrical helical spring of circular cross-section. After sudden release, torsional vibrations occur in each of the turns, resulting in a longitudinal vibratory motion of the free end of the spring.

As long as the spring is not coil-bound, the specified deflection s will be obtained with an axial load P if

$$s = 8\,PND_s^3/Gd_s^4 \quad .. \quad .. \quad .. \quad .. \quad (6)$$

where N is the number of effective turns of the spring, D_s is the mean coil diameter, and d_s is the wire diameter. For full utilization of the material, the numerical values used in eq. (6) should be chosen in such a way as to enable

the spring to be stressed up to its maximum permissible shear stress τ_h, i.e.,

$$\tau_h = 8\,PD_s k/\pi d_s^3 \quad .. \quad .. \quad .. \quad .. \quad (7)$$

where k is a correction factor depending on the ratio D_s/d_s, e.g., $k = 1{\cdot}1$ for $D_s/d_s = 14$, and $k = 2{\cdot}2$ for $D_s/d_s = 2$. The comparative values considered below are based on $k = 1{\cdot}23$, which corresponds to $D_s/d_s = 6$.

The natural frequency f_h of the fundamental vibration will then be obtained from

$$f_h = \frac{\tau}{4kG\sqrt{2}}\sqrt{\frac{Gg}{w}} \times \frac{1}{s} = \frac{C_3}{s} \quad .. \quad .. \quad (8)$$

High natural frequencies require the use of fairly large ratios D_s/d_s.

Belleville springs consist of a number of hollow truncated metal discs assembled back-to-back, so that two large ends in contact are followed by two small ends in contact, the purpose of this arrangement being to obtain a sufficient amount of total deflection. The elements are subjected to bending stresses under an axial load. The resilient column formed by a stack of such springs tends to have a variable stiffness, i.e., a spring rate which varies with the applied load. However, for certain geometrical proportions, a constant stiffness can be assumed for the calculations. With d_i = inner diameter of the small end and d_o = outer diameter of the large end of the conical disc, b = wall thickness, and h = height of internal taper (in the unloaded condition), and assuming that $d_i/d_o = 0{\cdot}5$ and $h/b \leqq 0{\cdot}75$, it can be shown that the resultant stiffness c of N conical discs fitted together end to end is

$$c = \frac{P}{s} = \frac{4Eb^3}{0{\cdot}91\,\alpha\,Nd_o^2} \quad .. \quad .. \quad .. \quad (9)$$

where P is the force, s the total deflection, E the modulus of elasticity, and α is a constant depending on the diameter ratio d_i/d_o. For full utilization of the spring material up to its permissible stress σ_c, the maximum force is given by $P = \sigma_c b^2/e$, where e is a constant. For $d_i/d_o = 0{\cdot}5$, $1/(0{\cdot}91\,\alpha) = 1{\cdot}58$, and $e = 1{\cdot}48$. The natural frequency f_c is then obtained from

$$f_c = \frac{\sigma_c}{2Ee}\sqrt{\frac{0{\cdot}91\alpha}{3\pi}}\sqrt{\frac{Eg}{w}} \times \frac{1}{s} = \frac{C_4}{s} \quad .. \quad (10)$$

In one-mass system calculations, it is usual to express the natural frequency f as $f = (1/2\pi)\sqrt{c/m'}$, where c is the stiffness and m' is the equivalent mass. Eq. (1), for example, can be written in this form by rearranging it as follows (with $c = EA/L_a$, where A is the area:—

$$f_a = (1/4L_a)\sqrt{Eg/w} = (1/2\pi)\sqrt{Eg\pi^2/4wL_a^2}$$
$$= (1/2\pi)\sqrt{(EA/L_a)/(4L_aAw/g\pi^2)} \quad .. \quad (11)$$

Consequently, since the actual mass $m = L_aAw/g$, the equivalent mass $m' = 4m/\pi^2$. For the stack of disc springs,

$$m' = 4m/\pi^2 \cong Nb(d_o^2 - d_i^2)w/\pi g \cong \tfrac{1}{4}Nbd_o^2w/\pi g$$

and this expression, used in conjunction with the stiffness c in eq. (9), yields eq. (10) given above.

Fig. 2, which is based on eqs. (3), (5), (8), and (10), shows natural frequencies f plotted against the reciprocal $1/s$ of spring deflection for the four types of springs investigated, without added masses and for tensile stresses and shear stresses ranging from 40 to 300 kg/mm². When full use is made of the permissible stress of the material, the natural frequencies of the springs are proportional to the constants C_1 to C_4. Constants C_1 and C_2 depend only on the properties of the spring material used, but C_3 and C_4 also depend on the geometry and dimensions of the spring.

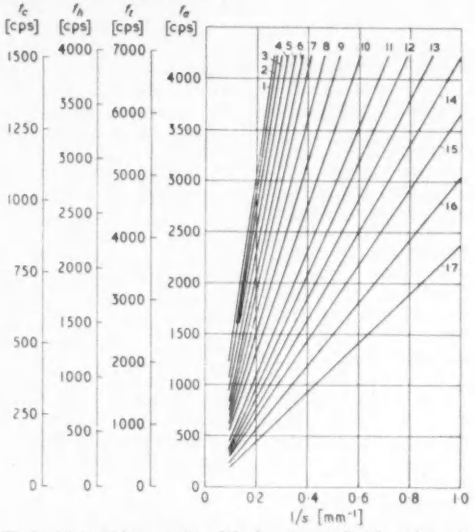

Fig. 2. Natural frequencies of the four types of springs shown in Fig. 1 as functions of the reciprocal $1/s$ of spring deflection, for various permissible tensile and shear stresses, in the case of a steel with a modulus of elasticity E of 21,000 kg/mm² and a modulus of rigidity G of 8100 kg/mm².

Constants:—$C_1 = 1{\cdot}23$ for $D_s/d_s = 6$; $e = 1{\cdot}48$; and $1/0{\cdot}91\alpha = 1{\cdot}58$ for $d_i/d_o = 0{\cdot}5$.

Curve No.	Stress [kg/mm²]	Curve No.	Stress [kg/mm²]
1	300	10	120
2	280	11	100
3	260	12	90
4	240	13	80
5	220	14	70
6	200	15	60
7	180	16	50
8	160	17	40
9	140		

If the comparison is based on equal values of permissible tensile, bending, or shearing stress, the torsion-bar spring reaches the highest natural frequencies for the same specified value s of spring displacement; this is followed by the tension-bar spring, while the helical spring and the Belleville spring give lower values. Such a comparison, however, is not representative of the true working conditions, since permissible stresses in a material vary according to the type of stress. For example, a chrome-vanadium steel capable of sustaining 110 kg/mm² in tension or bending should not be stressed beyond 80 kg/mm² in torsion but, if used in the form of Belleville springs, may be stressed up to 240 kg/mm². Under the assumption of full utilization of a given material up to its permissible stress for each type of loading, Fig. 2 indicates that the torsion-bar spring reaches the highest natural frequencies, whereas the helical spring has the lowest values.

It appears from the foregoing that helical springs are less suitable for very-high-speed switchgear than torsion-

bar or tension-bar springs. This is also borne out by the fact that the permissible shear stress of helical springs decreases as wire diameter is increased, so that, in the case of the chrome-vanadium steel mentioned above, the permissible stress will be less than 80 kg/mm² where the wire diameter is very large. Moreover, the "inactive" coils at the two ends of the spring do not contribute to its stiffness, but only to its mass. Finally, for a prescribed deflection s, high spring frequencies require correspondingly large values for the ratio D_s/d_s, resulting in greater space requirements to accommodate the large spring with its comparatively small number of turns; also, correspondingly larger masses will be required for connecting the spring to the contact pieces.

The Effect of Additional Masses on Spring Frequencies

Considering a tension-bar spring, one end of which is clamped and the other provided with an additional mass, i.e., a moving contact member, where f_a is the natural frequency of the bar without an additional mass and $f_a{}^*$ is the natural frequency with an additional mass. It can then be shown that, if m_s is the mass of the spring ($m_s = wL_a A/g$) and m_c is the additional end mass, the frequency $f_a{}^*$ can be determined from the relation

$$m_s/m_c = \beta \tan \beta \quad .. \quad .. \quad .. \quad .. \quad (12)$$

where $\beta = \pi f_a{}^*/2f_a$. This relation is also applicable to torsion-bar springs with and without an additional mass moment of inertia J_c; in this case, m_s/m_c is replaced by the ratio J_s/J_c (where J_s is the spring inertia) and $\beta = \pi f_t{}^*/2f_t$. Values of β can be determined graphically, typical values being $\beta = 0{\cdot}1$ for a m_s/m_c or J_s/J_c value of 0·01, $\beta = 0{\cdot}3$ for a value of 0·1, $\beta = 0{\cdot}9$ for a value of 1·0, and $\beta = 1{\cdot}4$ for a value of 10·0.

To find the natural frequency f^* (with additional mass), the frequency f (without additional mass) should first be determined from Fig. 2 for the required displacement s and the permissible stress σ or τ. The value of β is then found from m_s/m_c or J_s/J_c, so that f^* can be calculated from $f^* = 2\beta f/\pi$.

For disc springs and helical springs, with an equivalent mass $m_s' = 4m_s/\pi^2$, use is made of the relation $f = (1/2\pi)\sqrt{c/m'}$. With an additional mass m_c, the total mass is $m_s' + m_c$, so that the relation between mass ratio and frequencies is

$$\left(\frac{f^*}{f}\right)^2 = \frac{\frac{4m_s}{\pi^2}}{\frac{4m_s}{\pi^2} + m_c} = \frac{1}{1 + \frac{\pi^2 m_c}{4 m_s}}$$

$$\text{or } \beta = \frac{\pi f^*}{2f} = \frac{1}{\sqrt{(4/\pi^2) + (m_c/m_s)}} \quad .. \quad .. \quad (13)$$

It is of interest to note that this relation for β also applies to tension-bar and torsion-bar springs. Numerical evaluations confirm that the difference in values obtained by eqs. (12) or (13) is negligible. For $m_s/m_c = 0{\cdot}01$, the error is 2% of the correct value given by eq. (12); for $m_s/m_c = 10{\cdot}0$, the error is considerably less.

Practical Examples of Quick-Acting Switchgear

Actuating springs must always be so chosen that the switchgear will comply with the respective standard specifications governing the distance between the contact pieces in the open position for the nominal voltage considered. Thus, the maximum spring deflection must comply with a predetermined value. The mass of the moving contacts depends on the nominal current and on switchgear design. This mass (or moment of inertia in the case of rotational motion) should be kept as small as possible. As tension-bar and torsion-bar springs have been found to be particularly effective for quick-acting switchgear, their basic design calculations will be described further by means of the following examples.

For quick-acting switchgear, the displacement s and the mass m_s of the moving contacts are prescribed, their values depending on the nominal voltage, the nominal current, and the type of construction considered. With the spring material used at its highest permissible stress σ_a, the length L_a can be calculated and the natural frequency f_a obtained from Fig. 2. Then, trial values are taken for various spring cross-sections, and the corresponding spring force P and spring mass m_s are calculated in each case. The f_a-value and the mass ratio m_s/m_c serve to determine the frequency $f_a{}^*$ of the spring with the added mass, and thus also the actuating time t_s. With the results obtained in this way, it is possible to plot a curve of actuating time t_s against spring force P. The most suitable spring can then be determined on this basis.

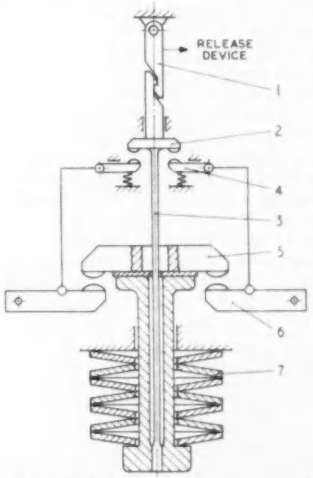

Fig. 3. Quick-acting short-circuiting device with a tension-bar spring in combination with a stack of conical disc springs.

One particular quick-acting short-circuiting device, using a tension-bar spring, as well as a stack of disc springs, is shown schematically in Fig. 3. After triggering the release device (1), the extremely rapid contraction of the tension-bar spring (3) brings down the primary contact plate (2) onto the contacts (4) and thus closes the circuit until the heavier main contact plate (5), actuated by the slower motion of the stack of disc springs (7), is pressed against the main contacts (6).

The dimensions of the tension-bar spring in this unit were determined on the basis of a spring displacement s of 2·8 mm, a distance a between contacts in the open position of 1 mm, and a weight W_c of the moving contact of 0·24 kg, using for the spring a chrome-vanadium steel with a permissible tensile stress of 110 kg/mm². The optimum dimensions for this bar were determined as $L_a = 585$ mm, and $d_a = 6{\cdot}13$ mm, giving a spring force of 3250 kg for a spring of weight $W_s = 0{\cdot}142$ kg. The

mass ratio m_s/m_c (or weight ratio W_s/W_c) was therefore 0·59. From the β-value and Fig. 2, the natural frequency of the spring with its added mass was determined as $f_a^* = 926$ cps, from which the contact-closing time t_s was calculated as

$$t_s = (1/2\pi f_a^*) \cos^{-1} [(s - a)/s] = 0{\cdot}15 \text{ millisecond.}$$

Subsequent practical tests on the completed construction proved this closing time to be correct.

A high-speed circuit-breaker actuated by a torsion-bar spring will now be considered as a second example. In such a unit, it is advisable to use a double-breaking arrangement such as that shown schematically in Fig. 4. Here again, the distance a between contacts in the open position is determined by the nominal voltage of the unit, and the required cross-section $h_c d_c$ of the moving contact plate is derived from the nominal current rating. The thickness d_c of the contact plate is made as small as strength considerations permit, in order to obtain for the contact plate a small mass moment of inertia

$$J_c = (w/g)\ (h_c + h_e)\ (b_c d_c/12)\ (b_c^2 + d_c^2)$$

Reducing the plate width b_c also results in a smaller value of J_c. However, a reduction in b_c also results in an increase in the angle of twist φ (for a given contact distance), thus increasing the length of the torsion spring and lowering its natural frequency. The width b_c should therefore be so chosen that the natural frequency of the entire system reaches a maximum value.

For the purpose of calculation, it is appropriate to begin by considering several values of width b_c and corresponding angles φ. Then, with various values for the spring length L_t, the required torsion-bar diameter d_t is determined for the values of b_c or φ considered, with calculations based on maximum permissible values of shear stress τ of the material, so that the diameter is evaluated as $d_t = 2L_t\tau/G\varphi$. The spring force P is calculated from the spring parameters as $P = \pi d_t^3 \tau/16R$, and the moment of inertia of the bar is obtained from $J_s = \pi w L_t d_t^4/32g$.

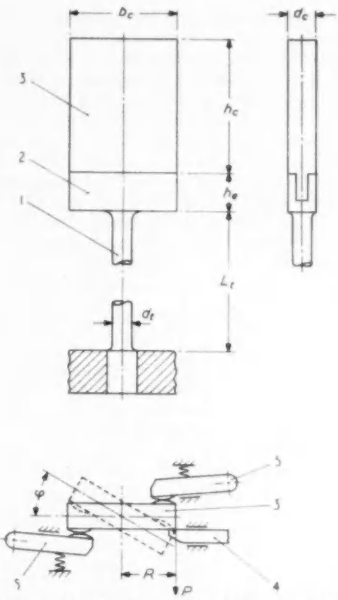

Fig. 4. Torsion-bar spring with contact plate.

(1) Torsion bar. (2) Holding member for contact plate. (3) Contact plate. (4) Release device. (5) Contacts.

Then, for each of the individual cases, as small as possible a value of d_c is chosen, corresponding to the width b_c and the spring force P. The corresponding value of h_c is calculated and the moment of inertia J_c of the contact plate determined, giving the inertia ratio J_s/J_c. From the β-values and the diagram in Fig. 2, the natural frequencies of the entire system can be determined. The contact opening times t_s are evaluated and plotted against spring force P, with b_c as parameter. This gives a family of curves, from which the most suitable arrangement can be determined.

Fig. 5 shows the basic features of a quick-acting d.c. circuit-breaker with a torsion bar (3) providing the actuating force. One end of the bar is rigidly attached to the circuit-breaker housing, and the other end carries a rotating contact (9). The bar is loaded by a hydraulic arrangement (1) and is rigidly connected to a roller-type release unit (5) via a linkage which is guided through an explosive cut-out (4). In the closed condition, the contact plate presses against the individually flexible contact fingers (8), which are connected to the busbars (7). The follow-up contact (10) is actuated by a bellcrank lever (6). The busbars are connected to the guide rails (11), above which the arc-extinction chamber (12) is situated. A ring-spring assembly (2) is used to damp out the impact occurring during the breaking movement.

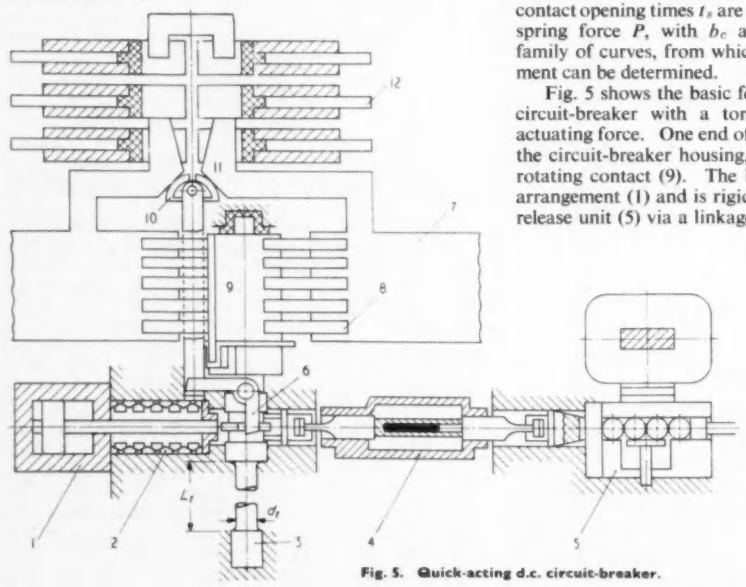

Fig. 5. Quick-acting d.c. circuit-breaker.

With a quick-acting circuit-breaker of this type, the main contacts open on an average within 0·35 millisecond after being released by the explosive cut-out, the mass of the releasing linkage having no appreciable effect on the actuating movement. Where a mechanical release system is used (mainly for manual switching operations), the additional masses are considerably larger and in this case the opening time is increased to about 2·6 milliseconds.

The torsion-bar spring of the d.c. circuit-breaker in Fig. 5 was required to have a distance a of 2×8 mm between contacts in the open position and a follow-up distance of 2×2 mm to the flexible contact fingers, so that the total displacement s' is 2×10 mm. The moving contacts had a cross-section of 3750 mm², and the torsion bar was made from a chrome-vanadium steel with a permissible shear stress τ of 80 kg/mm². With this material, the optimum values obtained were $L_t = 585$ mm for the bar length, and $d_t = 17{\cdot}1$ mm for the diameter; the moving contact plate had a width $b_c = 40$ mm, a height $h_c = 188$ mm, and a thickness $d_c = 20$ mm. The height h_c is increased by the additional height $h_e = 60$ mm for the holding and insulating elements.

Calculations based on these dimensions gave a spring force P of 4000 kg, a moment of inertia J_s of 0·00402 mm-kg-sec² for the spring, and an inertia J_c of 0·0292 mm-kg-sec² for the moving contact plate. With an inertia ratio $J_s/J_c = 0{\cdot}138$ and the corresponding β-value, the entire system with additional mass had a natural frequency f_t* of 310 cps (obtained from Fig. 2). This corresponds to a contact opening time of 0·33 millisecond, which was also attained in practice, although the mass of the moving parts of the locking device and also the bearing friction were neglected in the calculations. This was due to the fact that separation of the contacts occurred before the fingers had moved through the follow-up distance of 2 mm; because of the small force of their contacting springs the contact pieces cannot follow with the same high initial velocity attained by the rotating contact plate.

Photoconductive Cells and their Applications

By R. A. FARRALL

From *Control Engineering*, U.S.A.,
Vol. 8, No. 4, April 1961,
pp. 144–146, 7 illustrations.

ALTHOUGH the operating principle of photoconductive cells has been known for some time, practical applications were impossible until recent improvements in their design. Thus, early cells used silver contacts, which did not give a good ohmic contact in the low-voltage ranges. Now, however, that silver contacts have been replaced by indium contacts, almost any voltage within the dissipation and insulation limits of the cell can be used. Similarly, whereas photoconductive cells were previously potted in plastic, through which water vapour and other agents could penetrate and attack the photoconductive material, these cells are now hermetically sealed in glass enclosures. In addition, the originally poor sensitivity of the cell has now been improved by better doping techniques, with good ratios of light to dark resistance.

The construction of a typical modern photoconductive cell is shown in Fig. 1, from which it will be seen that the cell essentially consists of a support disc or wafer (1) made of ceramic or glass, coated with a thin film (2) of cadmium sulphide or cadmium selenide, on which rests at least one set of indium contacts (3). As distinct from other light-sensing devices, the photoconductive cell is not self-generating, its resistance decreasing with increasing light intensity, so that the current through the cell is a function of light intensity. When a photon impinges on the surface of a photoconductive cell, an electron hole pair is created. The electron pair rises to the conduction band where the hole recombines, but the electron continues to move, causing a conduction current. This conduction current, flowing through the photoconductive material, causes the change in resistance. With a greater light intensity, i.e., as the number of photons increases, more electrons are freed, and resistance further decreases; with less light, resistance increases.

Photoconductive cells utilize various types of contact configuration to give the cells a greater flexibility than photovoltaic cells. A typical cell has two contacts, as shown in Fig. 2a, the resistance being measured across the contacts. This type, which is easiest to manufacture, is used in cases where extreme sensitivity is not necessary or where the light source is very narrow. A configuration recommended for applications requiring maximum sensitivity or where use is made of a broad light source is shown in Fig. 2b. This configuration utilizes a large number of small interlocking contacts, each contact becoming a small resistor in parallel with the others. These interdigital contacts give the effect of a large number of photoconductors in parallel, lowering the resistance substantially and greatly increasing sensitivity without changing the area of the cell.

Commercially available photoconductive cadmium sulphide or cadmium selenide cells are designed for operating voltages of from 1 to 300 V, with maximum

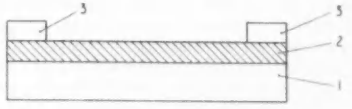

Fig. 1. Basic construction of a typical photoconductive cell.

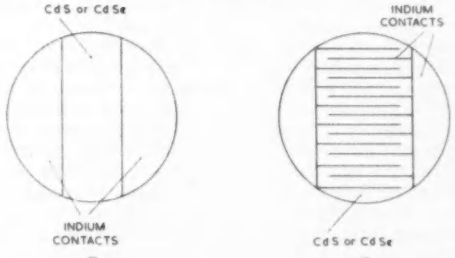

Fig. 2. Typical contact configurations in a photoconductive cell, showing (a) the most common configuration, and (b) an interdigital contact configuration, using numerous small interlocking contacts.

power dissipations of from 0·05 to 0·5 W, and for use at maximum operating temperatures of 160 to 185°F and minimum operating temperatures of from −50 to −120°F. The dark resistance of both cadmium sulphide and cadmium selenide cells is from 1 to 1000 megohms, with sensitivity resistances for cadmium sulphide cells ranging from 0·005 to 0·05 megohms at 10 foot-candles or from 0·0015 to 0·15 megohms at 100 foot-candles, and for cadmium selenide cells from 0·0012 to 0·012 megohms at 10 foot-candles or from 0·0005 to 0·005 megohms at 100 foot-candles. The corresponding time response to reach 75% of the reading at 10 foot-candles varies between 0·05 and 0·02 sec for cadmium sulphide cells and between 0·005 and 0·05 sec for cadmium selenide cells. The peak spectral response of the cadmium sulphide cells is between 5000 and 6200 Å and of the cadmium selenide cells between 6900 and 7400 Å.

Among the advantages of the photoconductive cell is its ability to respond to low light levels, this being due to its nearly unlimited sensitivity, combined with its ability to operate at high voltages. On the other hand, selenium photovoltaic cells have a limited sensitivity. To obtain outputs measured in milliamperes from a selenium cell requires hundreds or even thousands of foot-candles, whereas the only limit on the output of a photoconductive cell is its designed power rating. Also, since the photoconductive cell can operate equally well on alternating or direct current, there is no need to design a stabilized d.c. amplifier, as an a.c. amplifier can be used. Furthermore, the outputs from these cells are often high enough to operate relays without amplification. Other advantages of the photoconductive cell include its small size, thereby facilitating instrument miniaturization. In devices where the viewing angle of the light detector is important, small viewing angles can be designed with a minimum of optical accessories. In fact, exposure-meters are now available with acceptance angles of view of only 2 deg., and light levels as low as 0·001 foot-candle can be measured with a cell whose active area is only 0·004 sq. in. Still another advantage is that hermetic sealing has made the photoconductive cell virtually unaffected by environment. As an example, cells have been operated in environments with temperatures from +185°F down to −58°F without adverse effects, permanent changes in cell output as a result of these temperatures being no more pronounced than those in a standard selenium cell subjected to the same range of temperatures.

Nevertheless, it must be admitted that photoconductive cells at present have certain inherent disadvantages. Thus, for instance, the fact that they are not self-generating necessitates the use of an outside source. In most control systems, this would not be a disadvantage, as power is readily available, but the cell might be inconvenient in such applications as exposure-meters, since batteries would be required. Another disadvantage is their present cost, which is from about four to six times as high as that of selenium photovoltaic cells. At the same time, however, it is only fair to add that photoconductive cells are hermetically sealed in glass, and hermetically sealed selenium cells are from three to five times more expensive, as well as being considerably larger in size. A final disadvantage of photoconductive cells is that, although accelerated life tests indicate that they will be more than adequate for most measuring applications, difficulties such as cell drift, possibly caused by impurities sealed in during manufacture, have yet to be investigated.

Photoconductive cells have already been applied successfully in industry, three typical applications being their use as an automatic switch for street-lighting, as an instrument for measuring the turbidity of liquids, and as an assembly-line counter.

In the street-lighting application, the increasing resistance of the cell causes a relay to be energized when daylight diminishes to a predetermined level, thereby energizing a heater. The heater causes a bi-stable relay to trip, turning on the street light and at the same time disconnecting the heater. At dawn, the process of operation is reversed.

For measuring turbidity in liquids, two photoconductive cells are located at right-angles to one another on the outside of a transparent pipe carrying the liquid. A light source is projected directly at one cell and at 90 deg. to the other, the first cell measuring the light transmitted through the liquid, and the other the light scattered by the liquid, the latter cell receiving more light as the liquid becomes more turbid. The outputs of the two cells are initially adjusted to balance a bridge circuit when the turbidity of the liquid corresponds to a known value.

In the assembly-line application, the cell and projection lamp are so arranged that the cell is normally illuminated, thereby keeping its resistance low and causing a relay to be energized. When an object passes between the lamp and the cell, its resistance increases, tripping the relay and energizing a counter, and returns to normal when the object has passed. Light pulses up to 100 cps can be counted in this way.

Other applications of the photoconductive cell include their use as colour discriminators by placing colour filters over their active area and, in the same way, as indicators of colour density. In addition, these cells have been used in temperature controllers, a light source being blocked, causing a relay to trip, when the pointer of the temperature indicator reaches a predetermined point.

In conclusion, it may be said that, wherever the transmission, reflection, or absence of light can be used to measure a parameter directly or indirectly, photoconductive cells can be employed for measurement and control, with virtually no limit to the variety of applications possible. Furthermore, the application need not be of the on/off type, as photoconductive cells can respond to a continuously varying light source. In short, photoconductive cells, once neglected as light detectors, may well prove, by virtue of their improved stability, higher voltage range, and increased sensitivity, superior to many existing light-sensing devices.

The Use of Nickel Powder for Metallizing

(*Concluded from page 73*)

The major steps for nickel-powder metallizing are as follows:—(1) Degreasing; (2) preheating the area to 300 to 400°F, eliminating the condensation of water from the burning of hydrogen and oxygen and thus preventing the formation of rust which would lower the bond strength; (3) vacuum blasting; (4) metallizing; and (5) wire brushing.

Like most specialized metallurgical materials, metallized nickel powder has its limitations. Thus, if the coating is too thick or the surface not properly prepared, the coating will peel off. If the coating is too thin, it will not offer corrosion resistance. Furthermore, the coating has a low tensile and bond strength.

Magnetic Journal Bearings

By F. T. Backers

From *Philips Technical Review*, Netherlands,
Vol. 22, No. 7, 1960/61,
pp. 232–238, 12 illustrations.

The support of a rotating shaft in such a way that no material contact is made with the bearing is of importance in cases where friction or wear must be particularly small, where contamination by lubricants is inadmissible, or where a lubricating oil would decompose under the influence of radiation, e.g., in a nuclear reactor. One approach to the problem of making the shaft "float" is based on levitation by the application of magnetic fields set up by permanent magnets, the use of electromagnets being open to the objection that a continuous supply of energy is necessary to effect levitation.

Research on such a permanent-magnet bearing, the principle of which is illustrated in Fig. 1, has been carried out at the Philips laboratory at Eindhoven. In this bearing, a number of radially magnetized rings *B*, made of a ceramic permanent-magnet material, are fixed on a shaft *A*. Each of the two bearings shown in Fig. 1 has four rings *B* (a larger number could, however, be used), adjacent rings always having opposite polarity. The shaft *A*, together with its rings *B*, is placed in the field of an equal number of larger rings *C* of the same thickness, also made of the same ceramic permanent-magnet material, and these rings are fixed to the bearing housing *H*. The rings *C* have alternate polarities which, however, are opposed to those of the corresponding shaft rings.

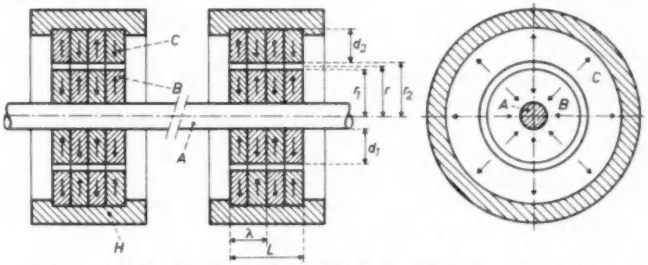

Fig. 1. Schematic representation of a shaft suspended in two magnetic bearings.

When, as a result of external radial forces acting on the shaft, the concentricity of the rings *B* and *C* is disturbed, the magnetic force at the place where the rings are closest is always larger than that at the diametrically opposite position. If each shaft ring is of opposite polarity to the corresponding outer ring, the resulting force tends to return the shaft towards the concentric position. Thus, as far as radial deviations are concerned, the shaft is in stable equilibrium. If opposing shaft and outer rings had the same polarity, equilibrium would still be possible, but would be unstable.

During an axial deviation, a force develops which tends to make the deviation still greater, so that in an axial direction the equilibrium is unstable. However, this axial instability can be controlled by letting the shaft abut against a stop when the deviation reaches a certain value. Another method, in which no material contact is made, will be discussed later.

In a magnetic bearing, the two characteristic quantities are the radial carrying capacity F_0, which is the external force on the shaft *A* necessary to bring the shaft rings *B* into contact with the outer rings *C*, and the radial stiffness *S*, which is the force per unit displacement in a radial direction.

It can be shown by calculation that, based on the assumption that magnetization varies according to a cosine function, the total restoring force *F* opposing displacement is

$$F = -A \exp(-b) \int_0^{\pi} \cos\theta \exp(-b' \cos\theta)\, d\theta$$

where $A = LrI_0^2/2\mu_0$, $b = 2\pi c/\lambda$ and $b' = 2\pi e/\lambda$.

In the above equation, I_0 = magnetization, μ_0 = the permeability of free space, c = maximum radial displacement of the shaft, e = eccentricity of the shaft, and θ = the angle measured from the position where the distance between the plates is a maximum. The meaning of the symbols *L*, *r*, and λ can be seen in Fig. 1.

The maximum value of *F*, i.e., the radial carrying capacity F_0, can be found by putting $c = e$, so that $b = b'$.

From a numerical calculation of F_0 as a function of b, it appears that F_0 has a fairly flat maximum for values of b in the neighbourhood of 1. It follows that the relation $b = 2\pi c/\lambda = 1$ defines a bearing of optimum dimensions. The axial length $\frac{1}{2}\lambda$ of each ring should thus be approximately three times the clearance *c*. The magnitude of the carrying capacity can then be determined as

$$(F_0)_{max} = 0{\cdot}655\ LrI_0^2/2\mu_0$$

and the radial stiffness *S*, again with $b = 1$, becomes

$$S = (F_0)_{max}/c$$

As mentioned before, these calculations are based on the assumption that magnetization varies according to a cosine function. However, the calculation can also be carried out for a discontinuously changing radial magnetization, e.g., for a square waveform, in which case the maximum carrying capacity becomes

$$(F_0)_{max} = 1{\cdot}20\ LrI_0^2/2\mu_0$$

i.e., about 1·8 times the value previously obtained.

Experimental Results

To verify certain theoretical relationships, a bearing was constructed in which λ and *c* could be varied. The fact that, for optimum results, $b = 2\pi c/\lambda$ should be approximately unity, can easily be substantiated, since there is no difficulty in measuring *c* and λ. It is not so easy, however, to check the value of $(F_0)_{max}$ since, to do so, the magnitude of I_0 must be known, and this cannot readily be measured with sufficient accuracy. Furthermore, it is essential to know whether magnetization varies as a cosine or as a square-wave function. Finally, there remains the question as to whether I_0 in the ceramic permanent-magnet material is constant in a radial direction. It is thus obvious that experiments

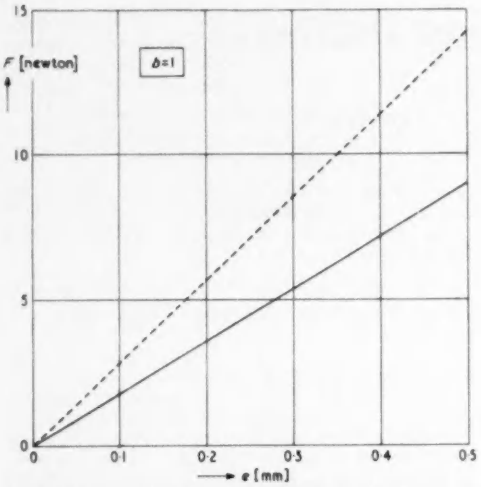

Fig. 2. Characteristic of a magnetic bearing with a parameter $b = 1$, the full line referring to measured values and the dotted line to values calculated for sinusoidal magnetization.

can do no more than provide a rough check of the formula for the carrying capacity.

Experiments were carried out with outer rings C with an o.d. of 60 mm and an i.d. of 35 mm, and two different types of shaft rings B and B', having an o.d. of 34 mm and 25 mm respectively, the i.d. being 9 mm for both types. At both ends of a shaft, which also carried a wheel, 40 shaft rings were mounted; two groups of outer rings C, each consisting of 40 rings, formed the fixed part of the bearings. The axial length of the rings was 1·5 mm defining the minimum value of $\frac{1}{2}\lambda$, so that, if n rings of the same polarity are placed together, $\frac{1}{2}\lambda = 1{\cdot}5\,n$.

The tests were carried out with the following combinations of rings:—

(1) Rings C and B with alternate polarity, so that $\lambda = 3$ mm. Since the clearance $c = 0{\cdot}5$ mm, b becomes approximately unity.

(2) Rings C and B in batches of ten adjacent rings of like polarity, so that $\lambda = 30$ mm and $b = 0{\cdot}1$ approximately.

(3) Rings C and B', so that $c = 5$ mm, $\lambda = 3$ mm, and $b = 10$ approximately.

The characteristics of these three types of bearings, in terms of force F [newtons] plotted against eccentricity e [mm] are given in Figs. 2, 3, and 4. The full curves represent the experimental results and the dotted curves the calculated values. It is clear from these illustrations that the radial carrying capacity and the radial stiffness are greatest for $b = 1$.

As far as the type of magnetization is concerned, a good approximation to a square waveform can be expected with combination (2), where λ is large, whilst with combinations (1) and (3) a cosine function approximates more closely to the actual form. For combination (2) in Fig. 3, the theoretical curves for both types of magnetization are given.

In the case of the rings B and C, the radial thickness d is approximately 12·5 mm, and in the case of rings B' approximately 8 mm. Since, in the derivation of the formula for F given above, it has been assumed for the sake of simplifying calculations, that d is relatively large with respect to λ, this formula appears only to combina-

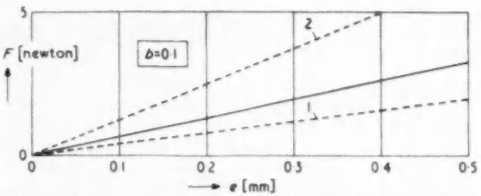

Fig. 3. Characteristic of a magnetic bearing with a parameter $b = 0{\cdot}1$, the full line referring to measured values and the dotted lines to calculated values (1) for sinusoidal magnetization and (2) for discontinuously changing magnetization.

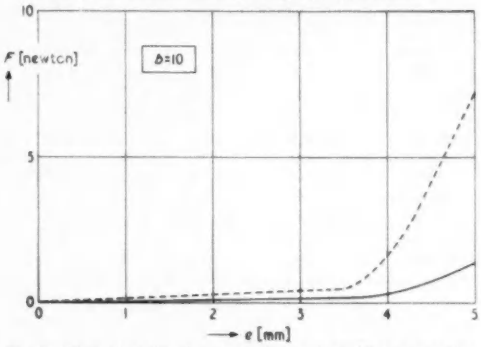

Fig. 4. Characteristic of a magnetic bearing with a parameter $b = 10$, the full line referring to measured values and the dotted line to values calculated for sinusoidal magnetization.

tions (1) and (3). The calculated curves in Fig. 3 (which refers to combination (2)) are therefore based on a more comprehensive analysis.

If the theoretical and measured characteristics are compared with each other, a large divergence of the curves in Fig. 4 will be noted. This is not surprising, since the theory supposes the clearance c to be small compared with the average radius r, and this requirement is not fulfilled here. On the other hand, in combinations (1) and (2), it appears that the differences between the theoretical and the measured curves are probably due to an error in the measurement of magnetization, which was measured in various ways, the average being $I_0 = 0{\cdot}17$ Wb/m², with a possible error of approximately 20%. Since $(F_0)_{max}$ is proportional to I_0^2, this error can lead to an error of approximately 40% in the final result. Assuming that the theory is correct and that in combination (1) magnetization follows a cosine function, it can be seen from the measured curve in Fig. 2 that $I_0 = 0{\cdot}13$ Wb/m². This value does not deviate by more than about 20% from the average measured value. If this "corrected" value is chosen for calculating the theoretical curves in combination (2) in Fig. 3, then the curve for a discontinuously changing magnetization more or less coincides with the measured curve.

It should be added that the measurements of I_0 are, in fact, measurements of the remanence or residual magnetization. This is only equal to the magnetization in the present situation (magnet in the field of another magnet) if the relative permeability μ_r is equal to unity, since an external field H increases the magnetization by the amount $\mu_0(\mu_r - 1)H$, which is zero only when μ_r is unity. This approximately applies in the case of the ceramic permanent-magnet material used in these tests.

Both the weight of the shaft ring and $(F_0)_{max}$ increase linearly with the length L; however, as the radius r of the

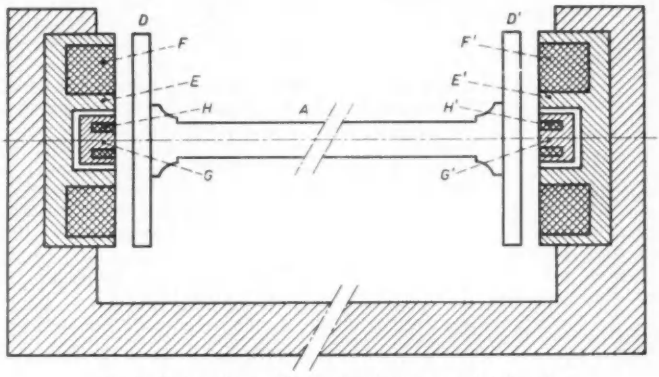

Fig. 5. System for stabilizing the shaft in an axial direction.

bearing is increased, the weight increases according to a square law, whilst $(F_0)_{max}$ increases only linearly. To avoid using up the whole radial carrying capacity to sustain the weight of the shaft itself in the case of large horizontal shaft assemblies, use can be made of the fact that, although the radial thickness d must be large enough (compared with λ), it need not be much larger than λ. It is therefore possible to employ hollow shafts of large diameter, fitted with rings of relatively small radial thickness. In this way, advantage is taken of the linear increase in $(F_0)_{max}$ with respect to r, while the weight now increases much less than proportionally to r^2.

It should be noted that the formulae for purely radial magnetization of the rings also apply to axial magnetization. One advantage of axial magnetization is that the direction of I is the same throughout each ring, making it possible to use a crystal-oriented ceramic permanent-magnet material with a higher remanence, this being a great advantage since $(F_0)_{max}$ is proportional to I_0^2. The preferred direction of magnetization in such a material should then coincide with the axial direction of the rings. It can be shown that, if the shaft and outer rings are not directly opposite each other, the carrying capacity is reduced, indicating that good positioning in the axial direction is important, particularly if λ is small.

To locate the shaft axially without making material contact, the stabilizing system shown schematically in Fig. 5 can be used. In this illustration, D and D' are discs made of a ceramic permanent-magnet material, E and E' are electromagnets excited by coils F and F', and H and H' are coils with cores G and G'. The self-inductance of each of the coils H and H' decreases as the distance to the respective opposing disc increases, making it possible to "measure" electrically the axial position of the shaft. H and H' form two arms of a bridge circuit in such a way that an error in the position of the shaft disturbs the balance of the bridge. Depending on the direction of displacement of the shaft from the central position, a phase-sensitive detector energizes the coil F or F', with the result that the shaft is drawn back to the equilibrium position.

Equipment for Hardness Testing at Low Temperatures

By L. L. France, R. T. Begley and H. Kohute

From *Materials Research & Standards (ASTM)*, U.S.A., Vol. 1, No. 3, March 1961, pp. 192–194, 5 illustrations.

Information on the temperature dependence of the strength of materials at low temperstures is necessary for low-temperature service applications and for fundamental studies of flow and fracture behaviour. While investigations of this type can best be carried out by conventional tension or compression testing, such testing programmes are frequently impractical.

Low-temperature hardness measurements supply data that can be correlated with mechanical strength at these low temperatures. It is true that several previous investigators have made low-temperature hardness measurements, but these measurements have been limited to temperatures obtainable by the use of liquid baths. Since there are no liquids readily available having a boiling point high enough or a freezing point low enough to cover the temperature range from −160 to −196°C, this range is difficult to investigate.

The equipment described in this paper was therefore constructed to overcome the disadvantages normally encountered with the use of low-temperature baths, particularly the problem of continuously varying the temperature. The essential components of the test chamber are shown schematically in Fig. 1, the only modifications necessary to adapt a standard Vickers hardness tester for this application being the replacement of the conventional indenter by an extended indenter (1) and the removal of a calibration plug from the weigh-pan of the machine to compensate for the increased indenter weight. The extended indenter, which is commercially available, has a standard 136-deg. diamond pyramid indenter. The refrigerant (nitrogen vapour) enters the test chamber (2) via a supply line (6) and passes through a perforated copper cooling coil (3) wound around the anvil (4), the specimen (5), and the bottom portion of the extended indenter (1).

The refrigerant storage and flow-regulating system is shown schematically in Fig. 2, in which a 25-litre Dewar flask (1), fitted with a pressure gauge (3) and a special transfer head, is designed in such a way that pressure build-up above the liquid nitrogen in the flask forces the liquid through the supply line (2) to the perforated cooling coil (9) in the test chamber (11). The flow and

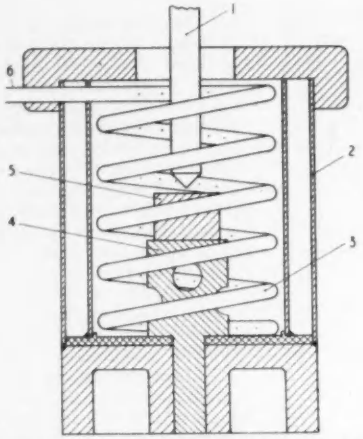

Fig. 1. Layout of the low-temperature hardness test chamber.

temperature control system consists of a needle-type control valve (4), a packless magnetic valve (5), and an anticipating-type 110-V a.c. temperature controller and recorder (6) connected by copper leads via an ice-bath reference junction (7) to a copper-constantan control thermocouple (8). The thermocouple bead is placed in a small hole on the surface of the specimen (10) to avoid any direct contact of the bead with the liquid nitrogen. The magnetic valve (5) is opened on demand for heat removal, supplying nitrogen vapour to the anvil, specimen, and indenter, while flow is regulated by the needle valve (4). With this arrangement, specimen temperatures in the range between room temperature and −196°C can be controlled to within ±2°C.

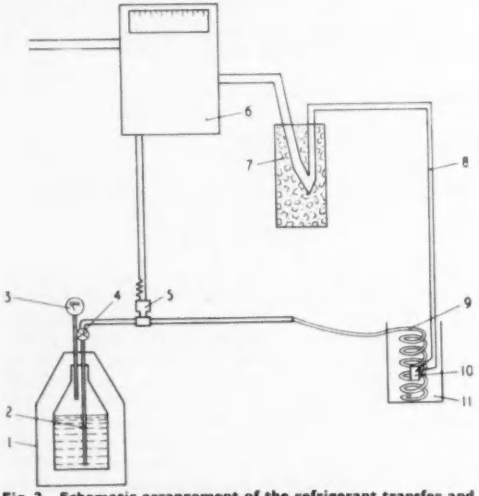

Fig. 2. Schematic arrangement of the refrigerant transfer and temperature-control system.

The test-chamber anvil is parallel to the base of the test chamber, and specimens are prepared so as to have opposite faces parallel, making it unnecessary to level each specimen prior to making impressions. The chamber is mounted on a traversing stage which allows a series of impressions to be made easily. Hardness determinations for several test temperatures can be made on the same specimen merely by moving or rotating the chamber. The normal Vickers cycle is used to make the hardness impressions.

No means for reading the impression size at reduced temperature is provided, the specimens being removed from the container and allowed to warm to room temperature. Impression size is then determined by means of conventional microscopic procedures. A correction can be applied to determine the impression diagonal D at the test temperature, using the relationship:

$$D = D_o [1 + \alpha (T - T_o)]$$

where α is the mean coefficient of expansion between the test temperature T and room temperature T_o, and D_o is the impression diagonal at room temperature. However, it can easily be shown that this correction at temperatures down to −196°C is negligibly small, being much less than 1 VPN.

Using this equipment, the hardness values of recrystallized electron-beam-melted columbium have been determined at temperatures between +20 and −196°C, these values ranging from about 90 VPN at +20°C to about 285 VPN at −196°C. The temperature dependence of these hardness values was found to be almost identical with that of various flow-stress criteria for the same kind of material.

The correlation of various criteria of strength and hardness values of columbium at low temperatures is shown in Fig. 3. This correlation is very good when made with the proportional limit in tension and compression, and with the flow stress after 3% and 6% compressive strain. Numerous investigators have shown a relationship between room-temperature hardness and ultimate tensile strength, and such a correlation could be expected at low temperatures. However, the data in Fig. 3 show that correlation between low-temperature hardness and ultimate tensile strength is not as good as the correlation with flow stress at relatively small strains.

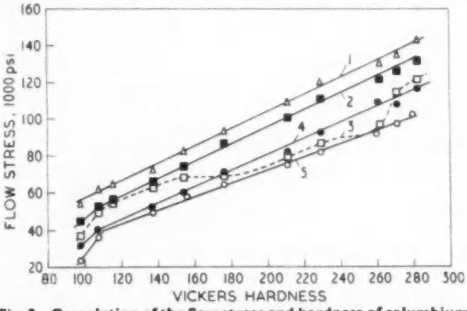

Fig. 3. Correlation of the flow stress and hardness of columbium at low temperatures.
(1) Flow stress at 6% compressive strain.
(2) Flow stress at 3% compressive strain.
(3) Ultimate tensile strength.
(4) Yield strength (0·05% offset) in compression.
(5) Yield strength (0·05% offset) in tension.

The relatively poor correlation between low-temperature hardness and ultimate tensile strength may be a result of anomalous flow behaviour at low temperatures. In tension tests, localized deformation is frequently encountered at low temperatures, resulting in very low uniform elongation values. This localized deformation is thought to be associated with local heating of the specimen, and this phenomenon could lead to questionable values of ultimate tensile strength.

The Ventilation of Thermal Power Stations

By L. OPPL and M. JOKL

From *Energetika*, Czechoslovakia,
Vol. 11, No. 3, March 1961,
pp. 122–128, 7 illustrations.

THE steady increase in the size of new generating units installed in power stations has led to a better utilization of power-station volume and has thus increased the importance of efficient ventilation in both the boiler-house and turbine-room for removing the heat dissipated by the generating installation and for ensuring suitable conditions for personnel.

The ventilation of boiler-houses, feed-pump annexes, and turbine-rooms is effected either by forced or by natural ventilation, or by a combination of both. No comprehensive data for calculating a ventilation system appear to have been published in the technical literature, and such data as are available are largely conflicting. For this reason, measurements have been carried out in a new power station comprising three 50-MW sets and a number of boilers, each with a steam-raising capacity of about 112 tons/hr.

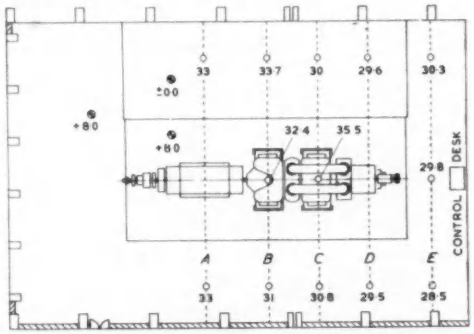

Fig. 1. Temperatures in the operating area of the first turbo-alternator set.

The heat dissipated in the turbine-room by the plant was calculated from the surface temperatures and the surface areas of the turbines, generators, and other equipment, the mean surface temperature t_F being about 60°C. The total heat Q dissipated by the turbo-alternator set proper was calculated as 46,000 kcal/hr. The heat dissipation Q from the feed-pump, with a mean surface temperature t_F of 53°C, was estimated as 1170 kcal/hr, from the ejector condenser ($t_F = 44{\cdot}2$°C) 985 kcal/hr, from the de-aerator ($t_F = 60$°C) 4700 kcal/hr, and from the two-stage evaporator ($t_F = 35$°C) 1530 kcal/hr. The total heat dissipation associated with one turbo-alternator amounted to about 55,550 kcal/hr, to which was added the heat dissipation of the pipework, estimated as 25% of that of the turbo-alternator, i.e., about 13,900 kcal/hr, making a total of about 69,450 kcal/hr per set, equivalent to no more than 0·16% of the total installed capacity. The floor area of the turbine-room was about 2960 m² and its height was 15 m, so that the total heat loading was only 4·7 kcal/m³-hr.

The air temperature in the turbine-room was measured at different points in the operating area, as well as in the space directly above it. Fig. 1 shows these measuring points (arranged in five sections A to E) for the first generating set, together with the corresponding temperatures. In each section, the temperature was measured at a distance of about 3 m from the boiler-house wall, in a plane through the axis of the set, and at a point about 3 m from the wall of the feed-pump annexe.

The vertical temperature distribution in sections A and C, with an outdoor air temperature of 21·6°C, is shown in Fig. 2. The average temperature gradient was calculated from this distribution as the arithmetic mean of the temperature gradients at the various measuring points and was found to be 0·327°C/m on one occasion and 0·257°C/m on another occasion, the average temperatures in the working area being 31·4 and 32·9°C respectively. The values of Baturin's coefficient $B = (t_p - t_z)/(t_o - t_z)$, where t_o is the temperature of the outgoing ventilating air, t_p is the air temperature in the working area and t_z is the outdoor air temperature, were determined and were found to be 0·69 and 0·76 respectively.

Connected with the boiler-house was a space in which were installed the de-aerator, heat exchanger, and feed-water tank. The heat losses from these items were therefore a part of the heat rating of the boiler-house. Calculated from their respective surface areas and temperatures, the heat dissipation Q from this equipment at an ambient temperature of 35°C was 8500 kcal/hr for the de-aerator with a mean surface temperature t_F of 50°C, 1180 kcal/hr for the heat exchanger ($t_F = 55$°C), and 12,100 kcal/hr for the feed-water tank ($t_F = 45$°C).

The total heat dissipation in the boiler-house was calculated from the thermal equilibrium. For this purpose, the air flow was estimated from the volume of air drawn into the boilers by induced-draught fans and from the volume discharged through the roof-lights by natural ventilation, the rate of flow of the combustion air being about 36 m³/sec and that of the ventilating air about 220m³/sec. The total thermal loading Q_v of the boiler-house, with four 112-ton/hr boilers operating under steam conditions of 93 atm and 510°C, was $5{\cdot}8 \times 10^6$

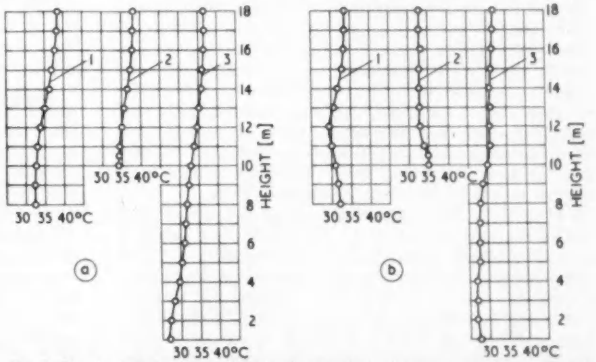

Fig. 2. Vertical temperature distribution in the turbine-room, (a) at section A, and (b) at section C in Fig. 1.
(1) At 3 m from the outer wall. (2) Above the middle of the turbo-alternator.
(3) At 3 m from the wall of the feed-pump annexe.

kcal/hr, the heat loading of the boiler-house being 27·4 kcal/m³-hr. With five similar boilers operating under approximately the same steam conditions the heat loading of the boiler-house was 33·2 kcal/m³-hr. Expressed as a proportion of the total thermal rating of the boilers, the heat dissipation was 1·59% and 1·54% respectively.

The amount of steam leaking into the atmosphere of the boiler-house was established from the number of changes of air and from the water content of the incoming and outgoing air respectively. The leakage attributable to one boiler with an average steam output of 112 tons/hr. amounted to 470 kg/hr, i.e., to about 0·42% of the steam raised. The ambient air temperature in the operating area and the temperatures of the discharged air under conditions of outdoor temperature of 21·2 and 28°C were measured. In the operating area of boiler No. 1, with an outdoor temperature of 21·2°C, the temperature in the operating area varied between 26 and 28·5°C. The vertical temperature distribution in the space between boilers No. 3 and 4 was also measured. With an outdoor temperature of 21·2°C, the average temperature in the operating area was 27·8°C, the average temperature of the discharged air was 39·5°C, and the average temperature gradient was 0·417°C/m. With an outdoor temperature of 28°C, these average values were respectively 35·8°C, 50·5°C, and 0·522°C/m, the corresponding values of the coefficient B being 0·360 and 0·347.

Choice of Ventilation Systems

Natural ventilation incorporating regulation of the rate of change of air is suitable for boiler-houses, as well as for turbine-rooms and feed-pump annexes, although, in the case of the two latter examples, excessive heat occurs usually only in the hot season. Since the specific thermal loading of power-station premises is expected to increase with growing unit sizes, they can reasonably be included under the heading of hot operating premises.

The advantage of natural ventilation lies first of all in its high reliability in operation, as a correctly designed system will fail only under unusual atmospheric conditions. This reliability is mainly due to the fact that it does not depend on the function of any mechanical equipment, while the system requires only a small amount of maintenance and is simple to operate.

Forced ventilation makes it possible to condition the incoming air by filtration and heating, or cooling as the case may be, the air heater or cooler being controlled by a thermostat. The disadvantages of forced ventilation are the high capital and operating costs of the equipment and the necessity for adequate maintenance, particularly as regards cleaning air filters and heaters, maintaining air-tightness of pipes and ducts, and lubricating and inspecting fans, motors, etc. In power stations, such maintenance is not always carried out properly, and this may cause a reduction in the efficiency of the ventilating system and may ultimately lead to its failure.

If the advantages and disadvantages of natural and forced ventilation systems are compared, the conclusion is that, for the ventilation of the generating units of steam power stations, neither method constitutes a satisfactory solution. The best solution for turbine-rooms and feed-pump annexes appears to be a ventilation system combining natural discharge of the air with a supply of air that is partly natural and partly forced, the natural supply being in use in the hot season and increasing the ventilation, as compared with the winter season. The forced-air supply must ensure the ventilation of spaces remote from the external walls and the direct ventilation of permanent operating positions, such as control stands. The air discharge from the turbine-room and feed-pump annexe can be arranged in two ways, i.e., by roof lights above the turbines and generators during the hot season, and by additional ports leading into the boiler-house for use during the winter period. This meets the requirement that the discharge ports should be located above the principal heat sources, although this is essential only in the hot season. In winter, the hot air discharged from the turbine-room and feed-pump annexe is useful in the boiler-house, where a large quantity of combustion air always has to be supplied. Such a system is advantageous where the combustion air is taken from the top of the boiler-house, as is frequently the case.

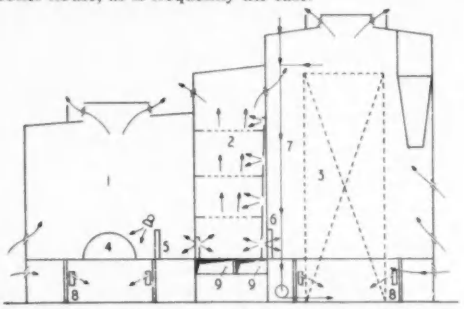

Fig. 3. Diagram of a recommended system of ventilation for power-station units.

(1) Turbine-room. (2) Feed-pump annexe.
(3) Boiler-room. (4) Turbo-alternator.
(5) Turbine control desk. (6) Boiler control desk.
(7) Combustion-air duct. (8) Air preheaters.
(9) Fresh-air intake.

In boiler-houses with natural ventilation only, the space between the boilers and the wall of the feed-pump annexe, generally in locations where boiler-house personnel have to work, is usually insufficiently ventilated. This space must therefore be ventilated by forced air drawn from outside and preheated during the winter. Thus, this combined heating method is also advantageous for boiler-houses. A diagram illustrating a recommended system of ventilation for power-station units is shown in Fig. 3.

Conclusion

The measurements carried out show that the heat dissipation from a boiler of about 112 tons/hr amounted on the average to approximately 1,425,000 kcal/hr, i.e., 1·4% of the total heat content of the fuel used, assuming a boiler efficiency of 90%. In the turbine-room it was found that the heat dissipation from one turbo-alternator set, including heat losses from pipes, amounted to approximately 70,000 kcal/hr, i.e., about 0·16% of the installed capacity. These figures are lower than those normally used in calculations.

For calculating natural-ventilation requirements, it is recommended, both on the basis of measurements and of data given in the technical literature, that the value of the heat gradient τ should be selected between 0·33 and 0·36°C/m for boiler-houses of 28 m height. For other values of height h, the corresponding value of the heat gradient τ can be taken as between $0{\cdot}33K$ and $0{\cdot}36K$, where $K = 26/(h - 2)$. If desired, the temperature of the discharged air can be fixed by means of the coefficient B, the value of which is about 0·35.

Investigation into the Phenomenon of Seizure

By A. P. SEMENOV

From *Wear*, The Netherlands,
Vol. 4, No. 1, January/February 1961,
pp. 1–9, 15 illustrations.

THE phenomenon of joining metals in the solid state is sometimes the main reason for severe damage to, and extensive wear of, surfaces subjected to friction. Such joining can also take place during technological processes such as cutting operations; in the case of plastic deformation of metals, this phenomenon is of particular importance, since it is responsible for rectifying faults in the crystal lattice. Other technological processes based on this phenomenon of the solid-state joining of metals are cold welding, pressure welding, ultrasonic welding, and roll bonding.It is advisable to consider solid-state joining as being constituted by two separate phenomena, i.e., sintering and seizure.

The phenomenon of sintering is possible at temperatures above the recrystallization temperature, or under very unstable conditions of the crystal lattice. It is a time-dependent phenomenon which has the nature of a diffusion process, and is very important for explaining high-temperature friction.

The phenomenon of seizure, on the other hand, is time-independent and does not have the nature of a diffusion process. It can take place at all temperatures, but pure seizure occurs only below recrystallization temperature.

It is possible to study the seizure of metals under conditions of friction, during cutting operations, or during mutual plastic deformation. Since, under conditions of friction or during cutting operations, temperature, pressure, and the value of plastic deformation at the points of intimate contact are unknown, it is more convenient to study the phenomenon of seizure by the method of mutual plastic deformation, in which case it is easy to obtain precise information about the conditions of contact.

There are many possible methods of mutual deformation for determining the conditions needed for seizure, e.g., rolling, deformation of rods, and deformation of sheet material with special punches. The last method, termed cold welding, is very convenient for the study of seizure.

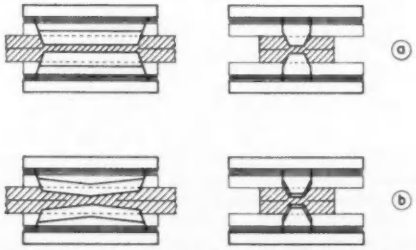

Fig. 1. Schematic representation of (a) plain punches, and (b) symmetrically inclined punches, for deforming sheet specimens.

The study of the mutual deformation of two sheet specimens by means of long narrow punches has shown that, if the width of the punches and the thickness of the specimens are equal, local deformation of the metal takes place near the centre of the volume between the deforming surfaces of the punches. Surface layers of the metal in the area of contact move away from the centre, together with oxide films, and, under very high pressures, new surfaces of the metal arise in the nascent condition. In this case, there is intimate contact between clean metallic surfaces, without any interference with the ability of the metals to seize or to join in the solid state. However, this is so only if the surfaces of the specimens have no lubricating films with very active molecules.

For the deformation of sheet specimens, some research workers use plain narrow punches (Fig. 1a) along which deformation is constant. This method suffers from the disadvantage that it is very time-consuming, since a large number of specimens, with gradually increasing deformations, have to be tested for the determination of seizure deformation. To overcome this difficulty, the author has developed a more convenient method, in which mutual plastic deformation of two sheet specimens is obtained with narrow punches such as those shown in Fig. 1b, in which each punch has two symmetrically inclined deforming surfaces of the same width as the thickness of the specimens.

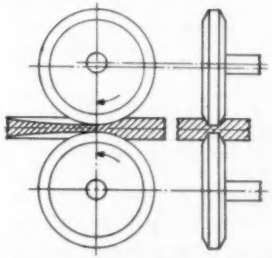

Fig. 2. Schematic representation of eccentric rolls for evaluating seizure deformation.

If the angle between the deforming surfaces of the punches is very small, the difference in conditions of deformation (and flow patterns) of specimens between plain and symmetrically inclined punches is practically negligible. The amount of deformation along the punches smoothly changes from the maximum in the middle to the minimum near the ends of the punches. It is then very easy to determine the value of seizure deformation with only one pair of specimens. For this purpose, the ends of the deformed specimens are separated up to the border of the junction, and the maximum thickness of the joined specimens near the border of the junction is measured to obtain the minimum seizure deformation.

For determining the seizure pressure, other pairs of the same specimens are deformed with plain punches, and the dependence of load on deformation is recorded. The load corresponding to any particular deformation of seizure can then be divided into the area of the deforming surface of the punch to obtain the specific seizure pressure.

This method is very convenient for determining the ability of metals to join or to seize, and makes it possible to study the influence of temperature, work-hardening, speed of deformation, pressure, chemical composition, etc. on the seizure of metals and alloys. Surface films of organic compounds, or thick oxide films, may have a marked effect on results, so that any such films must be removed.

In another test method, based on the same concept, the sheet specimens are deformed by two narrow rolls (Fig. 2) one or both of these rolls being mounted eccentrically to vary the deformation along the specimens.

These methods can also be used for evaluating the anti-seizure properties of different lubricants, with or without additives, the increase in deformation required to achieve seizure being a measure of their anti-seizure or anti-scuffing properties. Fig. 3 shows the effect of different liquids on the seizure deformations of commercially pure aluminium sheet of 3 mm thickness, while Fig. 4 shows the influence of the period of heating in air, at different temperatures, on the seizure deformation of aluminium specimens covered with films of engine oil.

The methods outlined above are suitable only for ductile metals and alloys, since brittle materials would be destroyed under deformations less than those needed to obtain seizure.

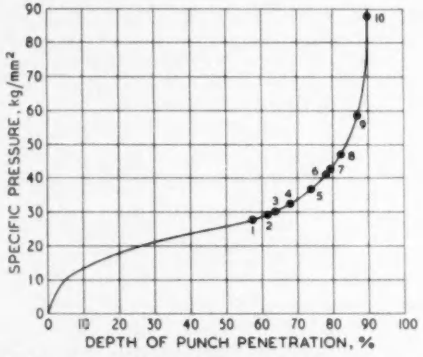

Fig. 3. The effect of different liquids on the seizure deformation of specimens of aluminium sheet.
(1) Dry scratch-brushed surfaces. (2) Dry surfaces, degreased by heating. (3) Surfaces lubricated with kerosene. (4) Surfaces lubricated with medicinal paraffin. (5) Surfaces lubricated with turbine oil. (6) Surfaces lubricated with water. (7) Surfaces lubricated with engine oil. (8) Surfaces lubricated with alcohol. (9) Surfaces lubricated with medicinal paraffin +50% oleic acid. (10) Surfaces lubricated with oleic acid.

As a rule, joining of specimens takes place at a specific degree of deformation for each metal and according to the conditions of the test. Plastic deformation not only creates clean surfaces and provides for their intimate contact, but also distorts the crystal lattice of the metals—an essential condition for seizure. Experiments have shown that various methods of increasing the energy of the crystal lattice, i.e., work-hardening, pressure, and temperature, assist seizure. If the temperature is higher, less pressure and deformation are needed. Work-hardened specimens need less deformation to seize, but require more pressure. If the pressure is higher, it is possible to produce seizure with less deformation or lower temperatures. As a rule, at temperatures below the temperature of recrystallization, greater deformation is needed than that required for obtaining intimate contact of clean surfaces. In such cases there exist, prior to joining, very large forces of repulsion between pure surfaces.

It has therefore been assumed[1] that, to produce seizure, it is not only necessary to establish intimate contact between clean surfaces, but also to increase the sum of the energies of the crystal lattice above some energy barrier. All metals have basically the same type of bond between atoms in the crystal lattice, but different metals have different types of crystal lattice. Assuming that the specimens are made of the same metal, that the surfaces are very smooth, and that the crystal lattices have the same orientation, it is possible to obtain spontaneous joining of two pieces to form one as a result of simple contact.

If the orientation of the crystal lattice of the specimens is different, or if there is contact of different metals with different crystal lattices, such joining is impossible without some distortion of the crystal lattice of surface layers. In actual fact, in the case of polycrystalline metals, it is impossible to get the same orientation of crystals in the contact surface. This explains the existence of some energy barrier which must be overcome before seizure can occur. The degree of misorientation, on the average, is constant for all cases of contact between two pieces of polycrystalline metal, and there is, as a rule, very little scattering in the value of seizure deformation.

Other research workers recognize the existence of an energy barrier (activation energy), but hold a different opinion about the mechanism of seizure. Thus, Parks[2] thinks that this mechanism is recrystallization, while Erdmann-Jesnitzer[3] believes it to be the result of diffusion. The author agrees with the concept of the energy barrier in these hypotheses, but in his opinion there is no need for mutual recrystallization or diffusion for seizure of metals to occur. These factors can have a positive influence on joining only after seizure and, even then, only above the temperature of recrystallization (the first stage of sintering). Some experiments carried out in the Soviet Union[4] and Germany[5] with very low temperatures have proved this point. It is impossible to suppose that seizure of such metals as copper, silver, and aluminium, at the temperature of liquid nitrogen, is a result of recrystallization or diffusion. The speed of deformation in these experiments was very low, and the rise of temperature of the specimens, as a result of plastic deformation, was negligible.

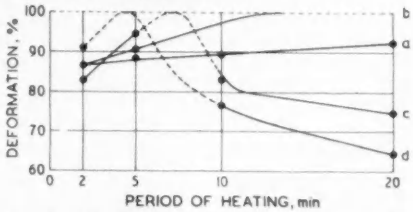

Fig. 4. The seizure deformation of aluminium specimens covered with engine-oil films as a function of the period of heating in air (a) at 200°C, (b) at 250°C, (c) at 350°C, and (d) at 450°C.

There are other hypotheses, i.e., that only the intimate contact of clean metallic surfaces is necessary for joining two pieces of metal, since the energy of the system is less for joined specimens. (The term "intimate contact" means that the distance between the surfaces is equal to the possible distance between atoms in the crystal lattice). The author can agree with these hypotheses only in the case of the same orientation of crystal lattices of specimens, but in practice this is an unrealistic situation, because the different abilities of various metals to resist seizure are attributed to the relative hardness of bulk metal and surface layers of oxide. However, if the relative hardness of oxide films is higher, these films are destroyed more easily and the tendency to seize is greater. These hypotheses are also refuted by experiments at different temperatures in an inert or reducing atmosphere with silver and copper. In these experiments

(deformation of sheet specimens in hermetically sealed capsules by means of long narrow punches) there were no films on the joining surfaces, but the seizure deformation and pressure changed very quickly with temperature. It therefore follows that it is possible to join the specimens practically without deformation only if the temperature is higher than the recrystallization temperature.

As regards the influence of chemical composition on the tendency to seize, it can be stated that an increase in concentration of dissolved components in homogeneous alloys (solid solutions) decreases the tendency to seize. Quenching, which increases the concentration of the solid solution, has the same effect. In the case of copper, it was found that there is a parallel change in seizure deformation, seizure pressure, hardness, and yield pressure with the change in the parameters of the crystal lattice, which results from foreign atoms becoming dissolved in the crystal lattice of the bulk metal. The basis of these changes is the change in the nature of the bonds between atoms in the crystal lattice, metallic bonds becoming more like covalent bonds.

With regard to the tendency for seizure to occur between dissimilar metals during friction, the seizure

(*Concluded on page 127*)

Corrosion-Resistant Pumps of Welded Titanium

By G. M. ITELSON

From *Tsvetnyie Metallyi*, Russia,
No. 2, February 1961,
pp. 74–78, 4 illustrations.

IN certain metallurgical processes carried out in Russia, various solutions, with pH-values of from 1·5 to 5·0, have to be used. These solutions, which have specific gravities of from 1·10 to 1·25 and are held at temperatures between 30 and 85°C, include sulphates and chlorides of nickel, copper, cobalt, iron, and sodium, containing from 0·5 to 15 grams/litre of free sulphuric acid, from 35 to 48 grams/litre of chlorine ions, and up to 1 gram/litre of copper.

As a result of corrosive attack by these solutions, pumps fabricated from a steel containing 18% chromium, 12% nickel, and 3% manganese became virtually unserviceable after a few days of operation, while pumps manufactured from high-silicon castings proved to be unsuitable for this application because of the excessive brittleness of their essential components. Castings made of a steel containing 18% chromium and 25% nickel gave more satisfactory results but, even in this case, the service life of components made of this steel did not exceed an average of three months and, with the more aggressive solutions, was limited to only a few weeks.

To overcome these difficulties, the production of corrosion-resistant pumps made of welded titanium was proposed in 1959, using a titanium alloy with an ultimate tensile strength of from 45 to 60 kg/mm², a yield point of from 38 to 50 kg/mm², an elongation of not less than 25%, a reduction of area of 50%, and a specific gravity of 4·5. This alloy is eminently suitable for forging and pressing in the hot state, and components of uncomplicated shapes can also be pressed in the cold state. The alloy welds satisfactorily in an atmosphere of argon or helium, or in a mixture of both gases, and the strength of the welded joints produced amounts to not less than 90% of that of the parent metal, while the corrosion resistance of the alloy to the solutions used in these metallurgical processes is, without exception, high.

In view of the high chemical activity of titanium in the molten state, it must be melted in a vacuum furnace. In this connection, it is necessary to bear in mind that the process of turning out titanium castings, even of medium weight, is very complicated technically, and insufficient is known about it. On the other hand, the fabrication of titanium pumps from pressings costs less, because the titanium components of a welded pump, such as the volute casing and impeller, are from about 40 to 50% lighter than the same parts cast in titanium; furthermore, the higher quality of the internal working surfaces of the pump fabricated from welded pressings of titanium alloy enables hydraulic losses resulting from liquid friction to be reduced considerably.

Titanium pumps, with capacities of 30 m³/hr and 200 m³/hr against a head of 30 metres, have been designed and are already in operation. In addition, a titanium pump, with a capacity of 400 m³/hr has been constructed and is at present undergoing tests. A longitudinal section of a 200-m³/hr pump is shown in Fig. 1. In this pump, the volute chamber of the casing (10) is made up of two symmetrical halves pressed from the titanium-alloy plate and welded

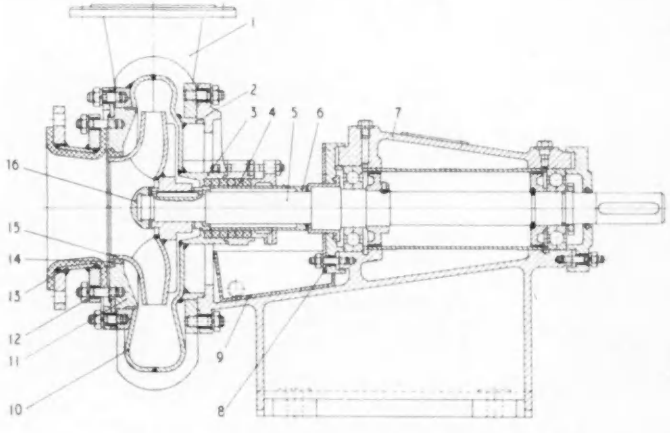

Fig. 1. Longitudinal cross-section of a welded titanium-alloy pump delivering 200 m³/hr.

together. The discharge branch (1), which is welded to the volute chamber and which terminates in a welded-on flange, either forged or machined from titanium-alloy plate, is also made up of two halves pressed from titanium-alloy plate and welded together. A tongue, pressed from titanium, ensures the necessary reduction in the clearance between the impeller (15) and the volute, and is welded inside the volute casing at the boundary with the discharge branch (1).

On the inlet side, a flange, made from titanium plate or machined from a titanium forging, is welded to the volute casing and is provided with threaded holes for securing the titanium cover (11). A titanium ring (2), with provision for mounting the casing on the housing, and another titanium ring (3), forming part of the stuffing-box, are welded to the opposite side of the volute casing (10). Lugs, with threaded holes for studs to secure the casing to the pump housing, are welded to the ring (2). The pump cover (11) is machined from a titanium forging and is fitted with a welded-on flange made from titanium plate or a forging. This flange serving to secure the cover to the flange of the volute casing (10). A special plastics sealing ring (14) is fitted in a recess in the cover (11), closing the gap between the eye of the impeller (15) and the cover and guarding against the possibility of undesirable metal-to-metal friction. The cover (11) is fitted with studs (12) for fixing the inlet branch (13), which is normally welded from titanium plate, and another flange is provided to join it to the pipeline.

The impeller (15), which has vanes of double curvature, is of welded construction and is made from rolled and forged titanium, subjected to the necessary machining operations. The impeller consists of pressed front and rear shrouds, a hub, and pressed impeller and balancing vanes, the impeller vanes being welded to the rear shroud over the full extent of the joint, while the front shroud is fixed only to the vanes at the points accessible for welding. The hub of the impeller is provided with a hole and a keyway for mounting on the steel shaft (5), which is protected from attack by corrosive media by a welded titanium sleeve (6) and a titanium cap (16). The shaft (5) runs in two ball bearings in the cast-iron housing (7), the cover of the ball bearing on the stuffing-box side being protected against corrosive attack by a titanium splash-ring (8). The stuffing-box packing (4) consists of graphited asbestos, which gives satisfactory performance in conjunction with titanium. Any corrosive liquid which may leak past the stuffing-box packing drops into a sump (9), from which it is drained off.

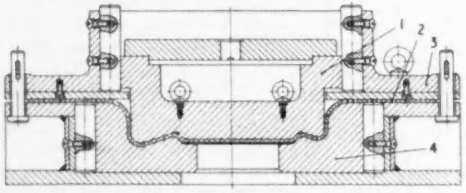

Fig. 2. Cross-section of the die used for pressing one half of the volute casing of a 200-m³/hr titanium-alloy pump.

Fig. 2 shows a cross-section of the die (1) and matrix (4) used for producing one half of the volute casing of this pump. On account of the appreciable depth of the titanium pressing (2), the die is provided with a special clamping ring (3). The volute casings of the first experimental titanium-alloy pumps were pressed from plate of 6 mm thickness, but there now appears to be no doubt that the production of high-quality titanium pumps with capacities of 200 m³/hr, using casings pressed from 5-mm plate, is quite feasible, and, in fact, the possibility of using plate of only 3 mm in thickness is being examined. Sections for the volute casing are pressed at a temperature of 350°C, and any scale is removed mechanically. To remove internal stresses after welding together the two halves, the casing is heated to about 550°C in an electric furnace and is held at this temperature for 45 min.

A cross-section of the dies used to press the front and rear shrouds of the impeller is shown in Fig. 3. Since the plate is deformed comparatively little when pressing the rear shroud (Fig. 3a), the design of the dies does not include a clamping ring for the plate, whereas this is essential when pressing the front shroud (Fig. 3b).

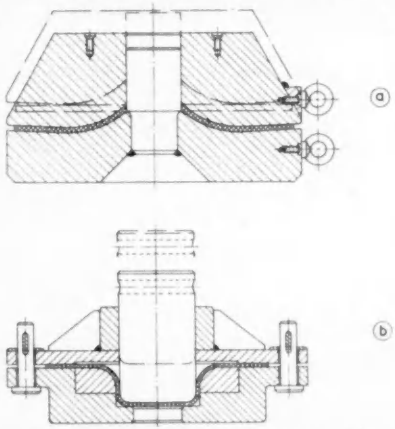

Fig. 3. Cross-section of the dies used for pressing (a) the rear impeller shroud and (b) the front impeller shroud of the 200-m³/hr titanium-alloy pump.

The components of the titanium pump are fabricated by simple manual argon-arc welding equipment, using a non-consumable tungsten electrode with a titanium degassing wire. During welding, the entire welding zone, i.e., the electrode, the welding arc, the weld pool, and the degassing wire, must be shielded in argon. It is also necessary to protect the face and the reverse sides of the part being welded by means of argon in the temperature zone above 400°C. The welding arc is set up by a d.c. generator with straight polarity, the tungsten electrode constituting the negative pole. In place of manual equipment, semi-automatic equipment, using a mixture of helium and argon in the proportion of 3 : 1, is also practicable under certain conditions.

In March 1960, two titanium pumps, each with a capacity of 200 m³/hr, were commissioned for duty on these metallurgical processes for the first time, and operated under the most arduous conditions. Two further pumps with an identical performance were put into service shortly afterwards, and in July two more titanium pumps began handling corrosive industrial liquids. The results obtained were outstanding, the pumps delivering the required quantities of process media without breakdown. Even more important, after six months of continuous operation they were not only still serviceable, despite the aggressive liquids handled, but showed no signs of corrosion whatsoever and no mechanical wear.

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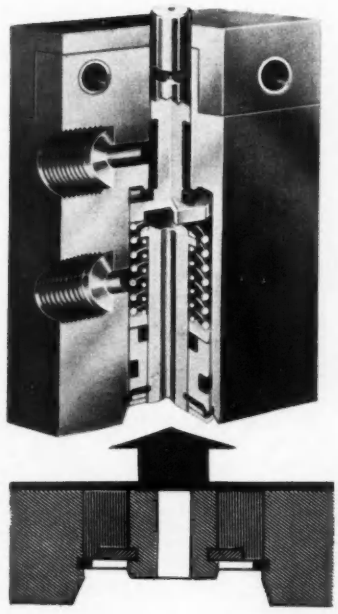

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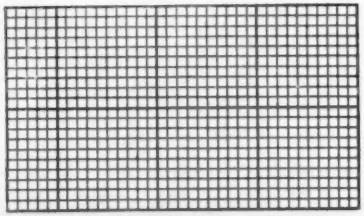

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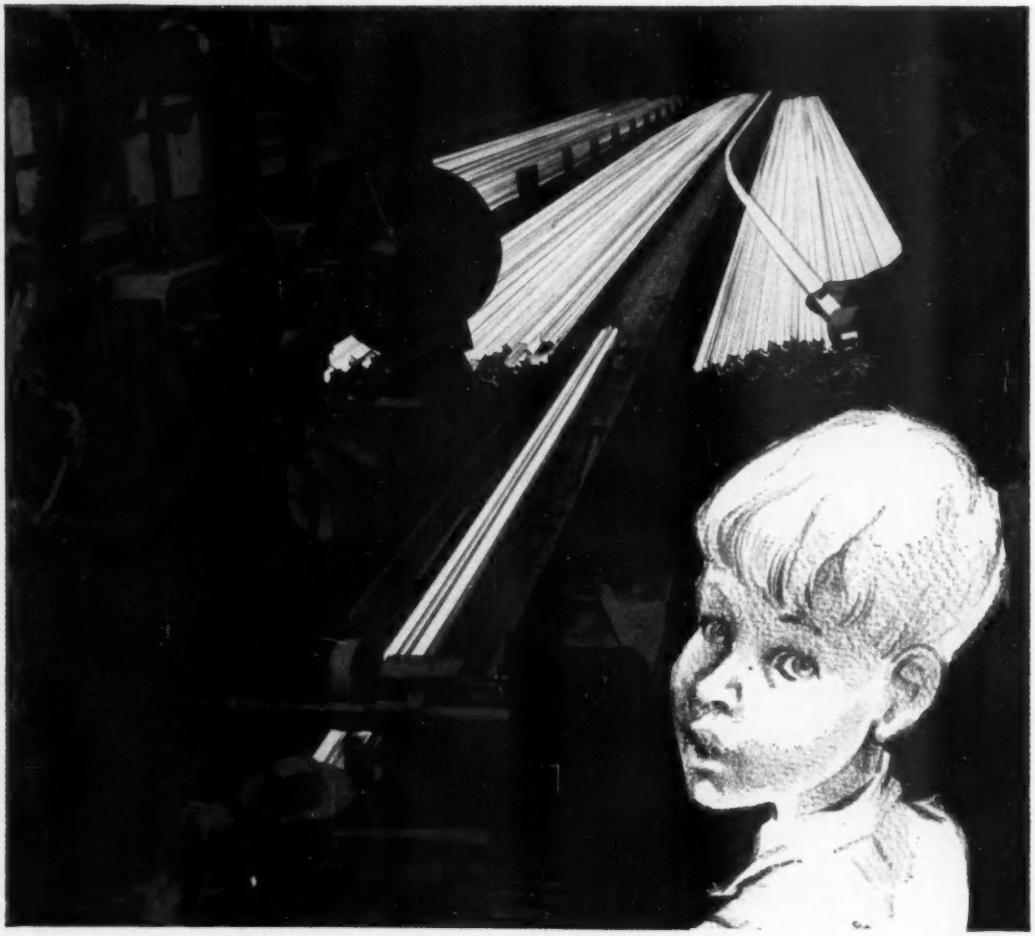


British Industrial Developments

Cleansing Plant for Diesel-Engine Cylinder-Head Castings

Even with the correct application of modern core-making techniques and special care in normal cleaning and shot-blasting, it is difficult to guarantee that diesel-engine cylinder-head castings are completely free from residual sand. To overcome this problem economically, these castings are now being subjected to a supplementary cleansing process at the Farington Foundries of Leyland Motors Ltd., to ensure that all intricate and largely inaccessible internal passages are entirely free from traces of sand. The process, which involves immersion of the castings in molten caustic soda, is carried out in special plant, designed by Leyland Motors Ltd. in close collaboration with Imperial Chemical Industries Ltd. and Thermic Ltd., using data obtained from trials carried out on a pilot plant at the Alkali Division of I.C.I. at Norwich.

Because of the nature of the process, the plant is housed in a separate building adjoining the castings-processing section, simplifiying application of the necessary safety measures and ensuring optimum working conditions. The plant is divided into four stages, i.e., preheating, immersion in molten caustic soda, draining and cooling, and washing in cold-quench and hot-rinse tanks. Following shot-blasting and rough cleaning, the castings are loaded into a wire-mesh basket and are conveyed on a gravity roller conveyor into a preheating oven, where they are subjected to a temperature of from 130 to 150°C for 25 min, to ensure that they are completely dry and also to reduce thermal shock in the caustic bath and to relieve the thermal load on the bath itself.

After preheating, the basket is picked up by one of two overhead monorail-mounted hoists, taken through screen doors, and lowered into the molten caustic-soda bath, which is constructed of welded mild steel, holds 3½ tons of caustic soda, and is heated indirectly by gas burners. The castings remain in the bath for 25 min at a nominal 500°C, and are then removed and allowed to drain over the bath for 3 min. The castings are drained for a further 20 min on an adjacent drain table, the hoist being disengaged to return and pick up the next basket. During this time, the castings cool down to approximately 250 to 280°C, lessening the thermal shock in the next stage, i.e., the cold-quench.

While there is a continuous flow of water through the cold-quench tank, the basket is lowered twice to rinse out the internal passages as thoroughly as possible. A feature of the tank is that it is deep enough for the basket to be lowered in and the top lid closed before the basket is lowered further for immersion. After 10 min, the basket and castings are transferred to a hot-rinse tank, where washing is completed by a further 15-min immersion, the basket being raised and lowered again to rinse out the interiors. There is also a small flow of fresh water through the hot tank, and the temperature is kept at 80°C, which is high enough for the castings to be self-drying after final removal from the tank.

To facilitate sludge removal, two trays are inserted into the bottom of the caustic-soda tank, and these are lifted out after each day's work, carrying much of the sludge with them, the remainder being removed by a long-handled scoop. With the type of work treated, the loss of caustic due to drag-out and sludge removal amounts to an average of 44 lb per ton processed, this being made up regularly by additions of flake caustic soda.

Special attention has been given to fume extraction to ensure very good working conditions, and powerful extractors are fitted over the caustic-soda bath and cold-quench tank. In addition, a curtain of fresh air is blown over the top of the bath to provide better ventilation control. The caustic-soda tank, draining table, and cold-quench tank are all completely screened off as a precaution against splashing, the operator manipulating the charges from outside the screen. Access and egress to and from the screened section for the basket are through double swing-doors. The floor in the draining area inside the screen and the working area outside are covered by a metal grille to allow splashed liquids to drain away and also to facilitate easy cleaning. The floor drains away into a sump which also collects the overflow from the cold- and hot-rinse tanks. The effluent, after the sludge has been separated, is not strongly caustic and is discharged into the normal sewage system.

Automatic Installation for Preparing Steel Blanks for Cold-Forging

An installation which will produce steel blanks of uniform mass and shape continuously and automatically has been designed and developed by Cold Forging Ltd., of Sunbury-on-Thames, Middlesex, a member of the Camp Bird Group. Three distinct operations can be carried out, such as cropping from bar stock, flattening or preforming of the cropped blank, and deburring or chamfering of the cropping burr inevitably produced. The units, marketed under the name of "Colforg", are linked to each other by a mechanical conveyor belt which feeds the blanks from one unit to the next.

The cropping machines are made in three sizes, capable of handling bar stock of 1, 2, and 3 in. diameter respectively. However, in the interests of overall operational efficiency, it may be desirable to use the cropping machine with a special tool which will also carry out the flattening operation. The barstock feeder for the machines is a standard unit, irrespective of whether the machine operates exclusively as a cropper or as a combined flattener/cropper. The individual bars are placed on an inclined bed fitted with rails, on which runs a carriage attached by a wire cable to a hydraulically operated drum. The front of the carriage engages the end-faces of the steel bars in such a way that, when tension is applied to the cable, a positive feed is applied to the bars, which are moved successively into the cropping tool at the operating rhythm of the machine.

The illustration shows a typical installation, comprising (left-centre) an automatic cropping machine, a preforming or flattening machine (centre), and a deburring or chamfering machine (right). In this installation, the cropped blank is gripped by a transfer conveyor which moves the blank to the next machine, the conveyor system consisting of two positively driven chains provided with carrier dogs, arranged to face each other. The

Canteen Catering

As in every other industry, the main factors governing the economics of the catering business are: quality of product, cost of production, and well-being of workpeople. Electricity measures up well to these three essential factors.

The outstanding virtue of electricity is better cooking, particularly in roasting and pastry ovens where high quality is more easily maintained than in ovens using other forms of heat.

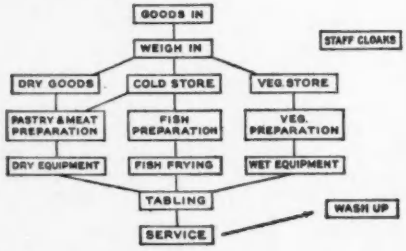
The cost of production varies somewhat with the type of food and the size of the establishment, but is usually between ½ and ¾ of a unit of electricity per meal. Cleanliness of electric cooking is axiomatic and provides better working conditions for the staff.

The actual size of the kitchen is influenced greatly by its shape and by the number of people catered for, but a rough guide is as follows:

KITCHEN TO DEAL WITH	SIZE
up to: 100 persons	5-6 sq. ft. per person
100-250 persons	4-5 sq. ft. per person
250-1000 persons	3-4 sq. ft. per person
over: 1000 persons	3 sq. ft. per person

Design

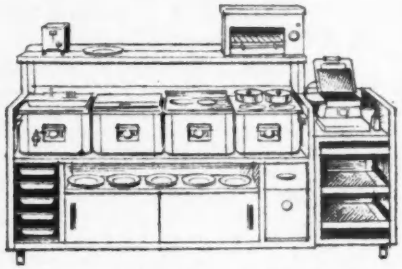
Where the kitchen is designed from the start for the full use of electricity, planning is simplified as the equipment can be placed where it is required without reference to the need for flues.



If an existing kitchen is already using other types of cooking equipment, however, electrical equipment can still be introduced item by item to bring increasing benefits.

Quick-service Equipment

The popularity of the quick-service establishment where the food is cooked at the service counter in full view of the customer is steadily growing, and this type of catering can readily be provided in the canteen by the installation of a Back Bar cooking unit, installed behind a section of the service counter.



The popularity of the mid-day joint and two vegetables is on the wane and the really up-to-date canteen should provide the welcome alternative of fresh food cooked on the spot.

Electric Catering Equipment

Electric catering equipment covers every single kitchen activity and some of the appliances in common use are:

COOKING. Ranges, boiling tables, steaming, roasting and pastry ovens, vegetable boilers, fryers, griller/toasters.

SERVICE AND WASHING-UP EQUIPMENT. Bains-marie, hot cupboards, tea and coffee machines, washing-up machines for the larger kitchen as well as sterilising sinks for the smaller, refrigerated cold-service counter and display cabinets, soda fountains.

PREPARATION. Mixing machines with attachments for chopping and mincing, etc., potato peeler, slicing machine.

QUICK-SERVICE EQUIPMENT. Infra-red (contact) grill, automatic toaster, griddle plate, automatic fryer, boiling plates, soup heaters, etc., and, the indispensable refrigerator.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Tel: TEMple Bar 9434.

Excellent reference books on the industrial and commercial uses of electricity are available — "Electric Commercial Catering Handbook" (5/-, or 5/6 post free) is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including commercial catering. Ask for a catalogue.

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relative spacing of the chains can be varied merely by adjusting the rails on which they run, thus providing the necessary adaptability to handle blanks of different sizes. The carrier dogs of each chain are always positioned opposite to each other, so that the space between them forms a pocket from which the blank cannot escape and in which it is moved at the correct operating rhythm to the next processing stage, i.e., the preforming machine. The conveyor carrying the cropped steel blanks passes through the preforming tool and then carries the preform to the chamfering machine, where it is dropped into a chute. The conveyor then returns to the cropping machine, passing underneath the preformer in its passage.

The preforming machine consists of a frame with an overhead platen mounted on four columns. The blanks enter the machine and are flattened by the upward movement of a ram to a fixed stop, the ram being hydraulically driven from a self-contained hydraulic unit coupled to the machine and located next to it. The hydraulic unit consists of a reservoir with hydraulic pump and valves, as well as a prefilling cylinder and the necessary controls and monitoring instruments. The operating cycle of the preforming machine is linked to that of the cropping machine, in this case by an electromagnetic clutch, driven by the feed chain on the discharge side of the cropping machine. This clutch actuates solenoid valves which, in turn, control the operation of the preforming machine. The preforming machine can be fitted with a simple flattening tool or it may be fitted with different tools which will impart an initial shape to the blank to facilitate easier development of the final form of the forging by subsequent cold-forming operations.

After completion of the flattening operation, the blanks are transferred by the same conveyor to the deburring or chamfering machine. The blanks enter the actual working zone of the machine on a pan-feeder, after which they are advanced to the chamfering tool by spring-loaded roller fingers which press the blank against the tool, so that the movement of the blank along the tool takes the form of a hobbing action. The actual chamfering tool is a bevelled inverted milling cutter, whose operating depth can be varied by a simple handwheel adjustment. This method of operation ensures that a uniform amount of chamfer is applied to blanks having a somewhat irregular periphery, as would be expected from raw material consisting of rough-rolled bar stock. The machine is independently driven by its own electric motor and includes provision for continuous separation of swarf from the coolant. The blanks are in contact with the deburring tool for approximately one-half of the circumference, the depth of engagement varying between minimum and maximum over this distance. The completed blanks are automatically ejected from the machine through a chute, and are then ready for heat treatment and surface treatment before the cold-forging operation.

High-Temperature Diffusion Furnaces for Transistor Production

New high-temperature diffusion furnaces, supplied by Royce Electric Furnaces Ltd., of Sheerwater, Woking, Surrey, have been installed in the Transistor Division of Standard Telephone & Cables Ltd., and are being used in the production of high-frequency, double-diffused silicon transistors. Measuring 6 ft in length and 2 ft 6 in. in width, with a working height of about 4 ft, these furnaces are self-contained units incorporating a floor-standing cabinet which houses all the electrical gear, including control instruments, switchgear, and transformers. Nitrogen, oxygen, and hydrogen atmospheres can be used, and the furnaces are designed to take work-tubes of either impervious fused alumina or transparent silica with an inner diameter of 2 in.

Each furnace, which is rated at 7½ kW, has both a preheat and a high-temperature section, the preheat section being mounted on wheels to enable it to be moved to and from the main chamber and locked in the required position. The preheat section has a heated length of 12 in., arranged in three zones and providing a range of temperatures from 200 to 1000°C. This section comprises a high-grade refractory tube housed in a refractory-lined chamber and carrying three separate heater windings of heavy-gauge nickel-chromium wire, heater currents being supplied through three variable transformers. The high-temperature section has a refractory tube in a brick-lined chamber of high-temperature refractory backed by thermal insulation. The heater length of 15 in. is controlled in one zone and provides any temperature required between 950 and 1300°C. The heating elements are of silicon carbide and are positioned vertically along the side walls of the chamber. Supply to the heaters is taken from a single-phase transformer having four primary tappings and a secondary winding with six coarse and six fine tappings.

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dently controlled and, within the specified temperature ranges, any desired temperature can be maintained in either section, irrespective of the operating temperature of the other section. Automatic temperature control is effected by indicating controllers, two instruments controlling the preheat section, and a third (anticipatory) controller operating the high-temperature section. A feature of the furnaces is the provision of even temperature zones, one 2 in. long in the preheat section, and the other 3 in. long in the high-temperature section. In these zones any specified temperature within their respective ranges can be maintained with a uniformity and a stability with time of ± 2° C. The furnaces are so designed that a fall in temperature cannot occur between these two zones.

New Grade of Tungsten Garbide

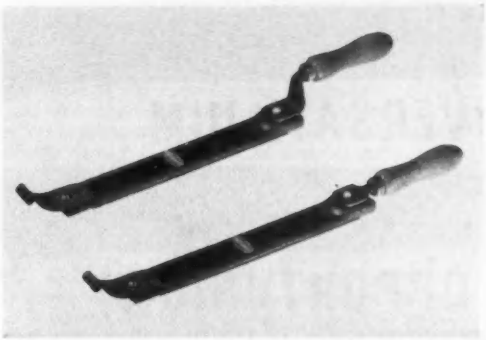
A new grade of tungsten carbide with an unusual structure and outstanding characteristics has been developed in Sweden by the Sandvik Steelworks Co. Ltd. Known as "SI Premium", this grade has now been patented in the U.K., and tips, inserts, turning tools, cutter blades, etc. made of this material can be obtained from Sandvik Swedish Steels Ltd., of Halesowen, Birmingham.

Because of its exceptionally high wear resistance, "SI Premium" has special merits when machining steel and steel castings, and it is stated that at least 30 to 40% more pieces per cutting edge can normally be expected when using this new grade. It should also be appreciated that the resistance to cratering of a carbide-tipped tool is mainly dependent on the amount of titanium and tantalum carbides present, and, in general, the percentage of tantalum carbide is very small. The new grade, however, has a high content of both titanium and tantalum carbides and therefore has a particularly high degree of wear resistance in respect of cratering, as well as of abrasion. Furthermore, the combination of the binding medium (cobalt) and the special structure of the material is such as to give this new grade a degree of toughness which far exceeds the average for this group of tungsten carbide grades.

Cutting, Shaping, Smoothing, and Trimming Hand-Tool

A new industrial hand-tool of the "Surform" type has been developed by Firth Cleveland Tools Ltd., of London, S.W.1, and is intended for applications involving the cutting, shaping, smoothing, and trimming of such materials as aluminium, copper, brass, and mild steel. The body of the tool is of all-steel construction and has a removable forward guide. As shown in the illustration, alternative handles are available, i.e., a straight wooden handle, or a cranked handle, adjustable laterally through 360 deg., with locating studs for positive positioning.

The working surface of the tool is a perforated blade of hardened and tempered tool steel, set with specially angled teeth. Although similar in principle to the well-known "Surform" blades, also produced by Firth Cleveland Tools Ltd., the new blade, coloured blue for easy identification, incorporates certain design features which make it suitable for an entirely different range of applications. Thus, the teeth are set further back in relation to each corrugation, so as to protect them when they come into contact with angular surfaces. The



blade corrugations not only control the depth of the cut, but also act as a buffer, giving smoother, easier operation and a longer blade life. In fact, tests have shown that the blade can withstand long periods of continuous use without impairing its efficiency. The teeth are set to a positive angle, so that the blade always cuts and cannot drag or push the material away, and are also set to cut to a constant depth, irrespective of the material. The tool is stated to possess excellent balance and cuts efficiently and quickly, even when used with only a very light pressure. In addition, it is capable of trimming the corners of hard materials without chattering or damaging the blade, while the perforations in the blade effectively prevent clogging.

X-Ray Non-Contact Thickness Gauges

Intended for use primarily with rolled or extruded products and suitable for a wide variety of materials, the "XactRAY" thickness gauge is manufactured in the U.S.A. by the Daystrom Company, who have recently established a U.K. technical sales and service facility, known as Daystrom Ltd., at Gloucester. Essentially, the gauge consists of three elements, i.e., an X-ray generator, which directs controlled beams of X-rays through the material being tested, an X-ray incidence unit or pick-up, which converts the transmitted electromagnetic energy into an electrical signal, and an electronic console, which computes and converts the signal into meter indications. Dimensional changes are displayed as a deviation from the preset nominal thickness on an indicator calibrated in any unit of density or thickness. In addition, means are provided for operating thickness-control and data-logging devices, and strip-chart recorders for permanent records, or for marking off-gauge material.

The X-ray generator and pick-up unit, which are mounted on opposite sides of the material under test, are designed to operate under severe conditions and are sealed against oil, water, and steam. In locations where they are liable to mechanical damage, special armoured gauges are available. A special feature is a device for inserting metal standards into the X-ray beam for calibration purposes, these standards being enclosed in a sealed chamber directly above the X-ray source and inserted into the beam by rotary solenoids. In this way, an operator at a remote position can select the exact thickness to be measured in increments as small as 0·0001 in., and normally a new thickness range can be set in less than 10 sec, including time for recalibration.

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The gauge is available in five models, giving a range of thickness from 0·00035 in. for aluminium foil up to 2 in. of steel plate. Any one model has a thickness range of up to 200 : 1; for example, the 60-kV generator is suitable for from 0·01 up to 2 in. of aluminium. Accuracy is better than $\pm 1\%$ of the thickness being measured, but this value can be improved to $\pm 0{\cdot}5\%$ on special order. Stability is guaranteed for at least 8 hr.

Electronic Die-Saver Control for Power Presses

The new "Robotron" electronic die-saver control announced by Radiovisor Parent Ltd., of London, S.W.19, is designed to provide continuous monitoring of power-press operations and to ensure that the component is ejected from the die before the press is allowed to commence the next stroke. In this way, the dies, the punch, and the entire press are protected against damage caused by non-ejection or incorrect ejection of the components.

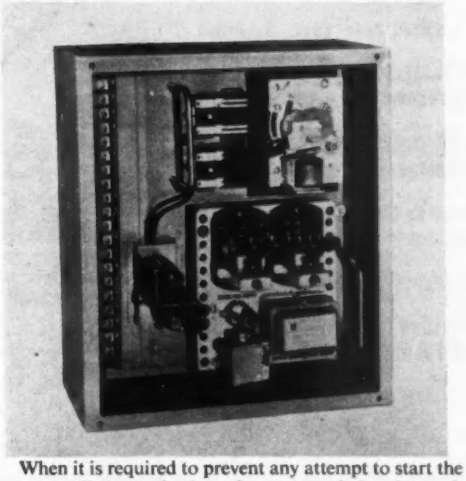
Essentially, the equipment consists of two parts, i.e., a control unit and a detection system. Where non-metallic parts are being pressed, a photo-cell detecting system is used and relies on the interruption of a light beam by the ejected component. In the case of metallic components, the control unit is fundamentally a high-frequency oscillator and an accurate fail-safe electronic timer, while the detection system is a detector head comprising an oscillator coil whose inductance is disturbed by the close proximity of moving metallic components. A range of detector heads is available to suit many standard conditions and component sizes, including heads with openings from 1 to 6 in. in diameter, suitable for mounting in a variety of positions. In addition, a special head can be supplied for use where it is required to pick up the signal as close as possible to the die or where limited space is a factor.

In operation, each metallic stamped part passing through or over the detector head gives rise to an electronic signal which is fed to the control unit. This signal operates a relay, which closes a set of normally open contacts, the relay remaining energized for a period chosen to bridge the time interval between two components. As long as the electrical impulses are repeated within the set time interval, the relay contacts stay closed but, when an impulse is missed through ejection failure, the relay becomes de-energized and its contacts open, disconnecting the press control circuit and stopping the press. A sensitivity control adjusts the electronic circuit to take into consideration the size of the stamped parts in relation to the area of the detector head. The unit will normally operate at a rate of 180 impulses per minute, though higher speeds can be accommodated, if required.

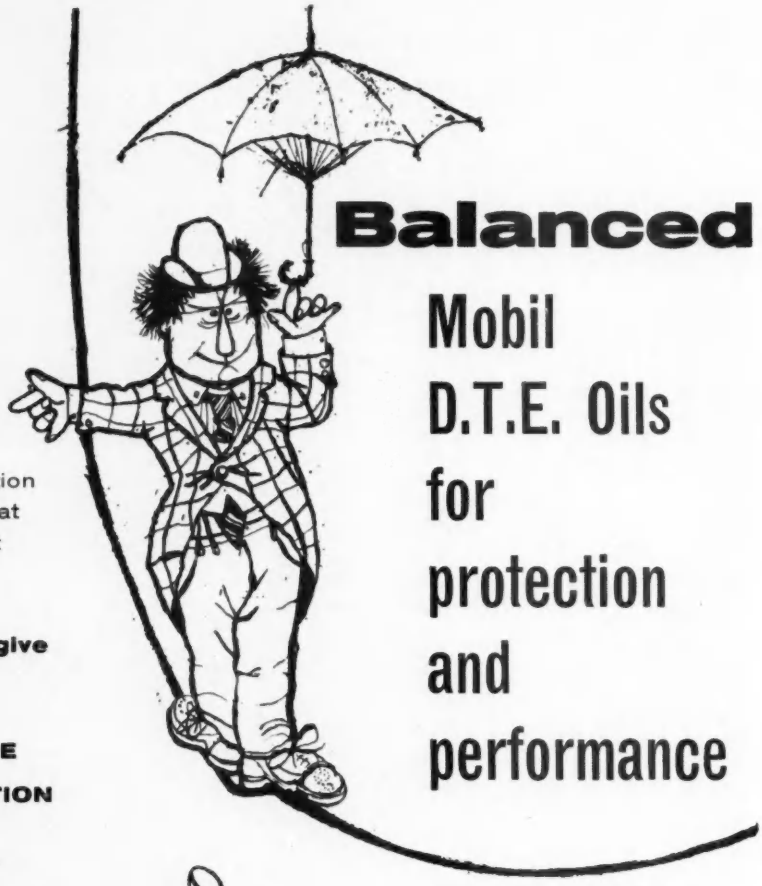
Combustion-Safeguard Relays

An improved "Protectoglo" combustion-safeguard relay, announced by Honeywell Controls Ltd., of Greenford, Middlesex, uses a flame-rectification principle and is suitable for monitoring gas- or oil-fired ovens, furnaces, etc., using without modification all accepted sensors, e.g., flame electrodes, photocell units, and infra-red and ultra-violet types. Other features include a fully plug-in chassis and purge-timer, automatic lock-out in the event of an unsuccessful ignition start, and a self-checking circuit to prevent start-up should any component become faulty or should the sensor already detect flame.

When flame is present, rectified current is fed to the relay into one grid of a double-triode electronic tube. The triodes are connected in such a way that the output current will energize the control relay on flame failure and no rectified current can be produced, the tube output current dropping to zero, causing the control relays to cut out. The self-checking safe-start circuit in the relay includes a safety-switch and a manual reset-button. If a fault is detected during start-up and the safety switch is in the safety position, the system cannot be started until the unsafe condition is corrected and the manual reset-button is actuated.



When it is required to prevent any attempt to start the burner until the expiration of a measured time interval, during which the combustion space can be thoroughly purged of any accumulation of unburnt fuel, a purge-timer is supplied. This timer can be seen in the upper right-hand corner of the illustration, which shows the relay with its cover removed and the plug-in chassis, and is fully adjustable for periods of from 2 to 15 min, or alternatively from 4 to 30 min, at the end of which an external signal light indicates that the burner can now be started.



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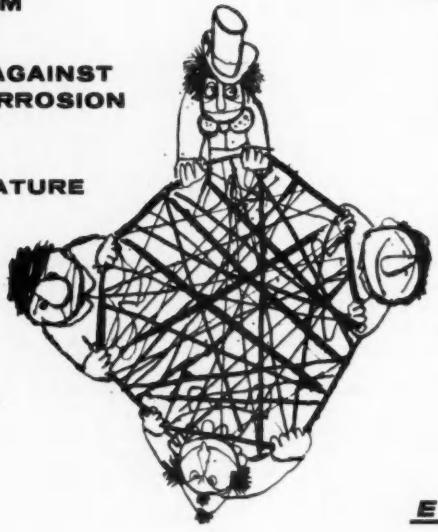

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ADDITIONAL ABSTRACTS

The Built-up Nose on Metal-Cutting Tools when Machining Ferrous Metals

By W. B. HEGINBOTHAM and S. L. GOGIA

From a paper presented at a meeting of *The Institution of Mechanical Engineers*, London, April 18, 1961, 16 pages, 29 illustrations.

IN this paper, quantitative information is given about the shape, size, structure, and general behaviour of the built-up nose (i.e., the cap of work-hardened material attached to the rake face of a metal-cutting tool) when machining ferrous materials. Using tungsten carbide tools on carbon steels, it has been found that built-up noses persisted over a wide ranges of cutting speed and feed. For instance, built-up noses were observed at speeds as high as 450 fpm and were found to persist even with ceramic tools. Orthogonal cutting conditions were used in all cases, in order to reduce the number of geometrical variables to a minimum.

Chip-tool-work-piece photomicrographs were obtained by an abrupt stopping technique, and methods of measuring and assessing the features of a built-up nose have been formulated. The various forms of built-up nose so observed have been classified and the conditions under which each type exists established for the particular materials used. The effect of cutting speed and feed on size of built-up nose has been ascertained and all results have been reduced to a single curve, using non-dimensional parameters.

In between the chip, the work-piece, and the built-up nose a particular type of deformation zone exists: this has been examined, and the features observed are discussed and the reasons proposed. A typical deformation zone is studied and flow fields established which imitate the type of distortion found in the chip and work surface and the region just ahead of the tool.

In this investigation, it was found that the length of the built-up nose varied in all instances from 1 to 20 times that of the undeformed chip thickness. A built-up nose can be generally or merely locally unstable, and can be divided into four distinct classes of form, i.e., a positive wedge, a negative wedge, rectangular, and layer-type. The disposition of the fracture points of each layer in the built-up formation determines the division of debris between the chip and the tool, and this division is not the same for each class of built-up nose. In no instance was a very-sharp-edged built-up nose observed which conflicted with the observations of past experimenters, regarding an edge of "razor-like sharpness cleaving through the work material."

Distributed Amplifier Tubes

By T. KOJIMA

From *Rev. of the Electrical Communication Lab., Japan*, Vol. 8, Nos. 7–8, July–August 1960, pp. 343–368, 26 illustrations.

DISTRIBUTED amplifiers make it possible to amplify an extremely wide band signal, and considerable work on distributed amplifiers made up of several conventional tubes has been carried out. Distributed amplification in a signal tube is also obtainable by arranging transmission-line types of electrodes in the tube and several tubes of this type have been proposed. In such a tube, amplification of the signal is achieved in the same manner as in distributed amplifiers. It is quite possible to construct a tube which has the same gain-band characteristics as that of an amplifier made with many conventional tubes. Furthermore, as the electrodes of these tubes are made of perfectly distributed lines, there is no limit to the frequency band that can be amplified.

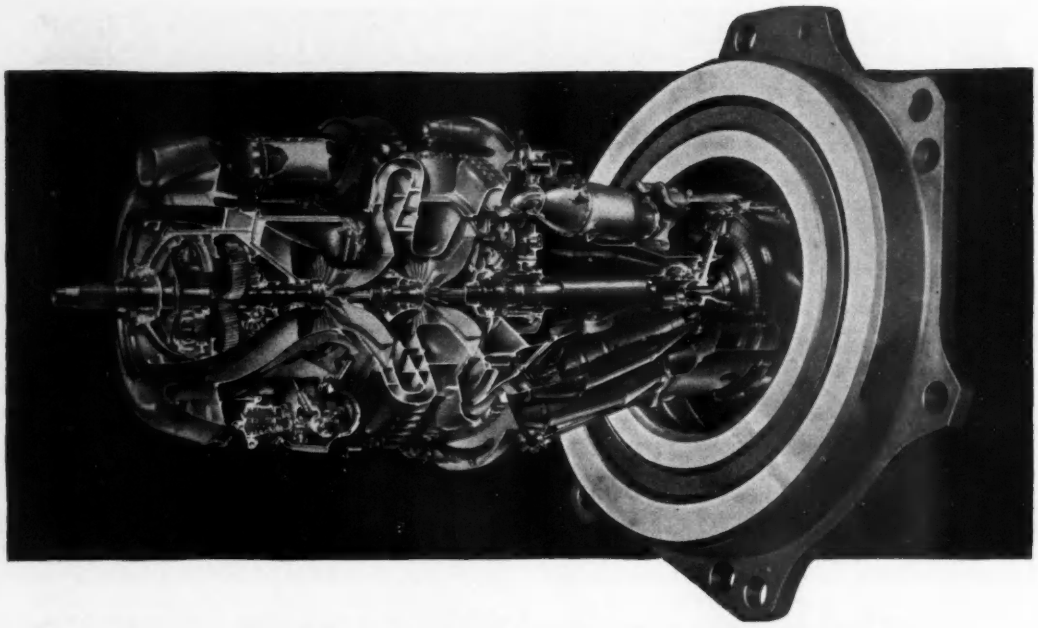
In the distributed-amplifier tube, the anode and grid are helical lines, and the velocity of propagation of electromagnetic waves on the anode line is equal to that on the grid line, the signal being amplified during its travel from the input of the grid line to the output of the anode line. In this paper, the general theory of the distributed-amplifier tube is presented, together with an analysis of the effects of various factors, such as the lowering effect on gain caused by line losses, the propagation-velocity difference between the grid and anode lines, and electron-beam scattering. In addition, with a view to facilitating the design of these tubes, a method of calculating their characteristics is described, together with details of the construction and measured characteristics of two experimental tubes.

Properties of Flash-Welded Molybdenum

By E. G. THOMPSON, H. BINDER, and H. COLLINS

From *Welding Journal*, U.S.A., Vol. 40, No. 4, April 1961, pp. 160s–166s, 13 illustrations.

AT room temperature, commercial arc-cast molybdenum has reasonable ductility in the severely cold-worked condition, while as-cast or recrystallized material behaves in a brittle manner. The lack of ductility in the as-cast condition has proved to be caused by quantities of oxygen and, to a lesser extent, nitrogen. The utilization of flash welding has certain advantages which should result in optimum obtainable joint properties. Because the time required to create the weld is short and because the upsetting forging action during welding expels all molten and some plastic material, the possibility of weld contamination is reduced. Furthermore, if properly made, the joint created consists of a fine-grained, recrystallized, and partially worked microstructure. The elimination of a cast structure and the potential improve-



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ment in the ductility of the recrystallized microstructure of the weld by a significantly finer grain size are the advantages of flash welding compared with fusion welding.

For these and other reasons, a programme was initiated to investigate the possibility of utilizing flash welding in the fabrication of molybdenum parts. As a result, a technique for the flash welding of arc-cast 0·5% titanium-molybdenum alloy bar stock has been developed and the as-welded properties of the joint have been determined at room temperature. Flash-welded bars have been processed into sheet material, and the properties of the cold-worked specimens have been ascertained over the temperature range of 2200 to 3200°F.

The programme reported in this paper shows that arc-cast 0·5% titanium-molybdenum alloy can be successfully joined by the flash-welding process, and that satisfactory joints can be made without protective atmospheres. As-welded joint properties compare favourably with parent-metal properties, considering the difference in metallurgical structures. Fabrication of components fur use in the as-welded condition is therefore feasible. Furthermore, flash-welded specimens can be successfully processed into sheet material. The tensile properties of the joint after such processing approach or equal those of the parent metal in the useful temperature ranges for molybdenum-base alloys. The possibility of using flash-welded rings or cylinders as preforms for the production of a considerable variety of hardware by various metal-moving techniques is also demonstrated.

A Simple Stress-Corrosion-Cracking Test for Copper Alloys

By D. H. Thompson

From *Materials Research and Standards (ASTM)*, U.S.A., Vol. 1, No. 2, February 1961, pp. 108–111, 3 illustrations.

The properties of materials can be determined by a great variety of tests. There are relatively few standard corrosion tests, however, and there is no standard test for determining the resistance of a metal to stress-corrosion cracking. The stress-corrosion cracking of copper alloys is believed to be the result of the simultaneous action of stress and a corrodent comprising ammonia, air, and water. Preferably, the corrodents should exist in the gaseous state, although the actual attack may take place in a liquid film on the metal surface. It follows that a stress-corrosion-cracking test for copper alloys must present metal under a known or reproducible stress to an atmosphere containing constant amounts of ammonia, air, and water vapour. In order to maintain constant atmosphere composition, some method of renewing the gases must be adopted, and there must also be a way of detecting or measuring the progress towards failure.

In the test described in this article, specimens of cold-rolled copper-alloy strip are bent sround a mandrel until their ends touch and are held in position by a twist of copper wire passed through holes in the ends of the specimen. In this way, a tensile stress is produced in the outer fibres at the bend. These tear-shaped loops are then exposed for definite periods to the vapours arising from a concentrated solution of ammonium hydroxide at room temperature. Before and after successive exposure to the ammoniacal atmosphere, each loop is unfastened and is allowed to spring back into its natural U-shape, and the distance between the ends is measured in each case, the reduction in this distance being a measure of the progress of stress-corrosion cracking.

It will thus be clear that the advantages of this test are its simplicity, the almost negligible amount of equipment required, and the quantitative measure obtained of the progress of cracking. Its disadvantages are the inability to meaure or vary the applied stress and the use of cold-rolled specimens. Nevertheless, the test is believed to constitute a reliable accelerated method of determining the relative resistance of copper alloys to stress-corrosion cracking in natural environments.

Application of the Flash-Temperature Concept to Cam and Tappet Wear Problems

By A. Dyson and H. Naylor

From a paper presented at a meeting of *The Institution of Mechanical Engineers*, London, April 11, 1961, 28 pages, 22 illustrations.

In the lubrication of a modern automotive engine, the cams and tappets are among the most sensitive parts and are expected to become more difficult to lubricate as engine speeds increase. This paper deals with the two types of cam and tappet distress occurring mainly at high engine speeds, i.e., scuffing and polishing (or burnishing). The occurrence of these phenomena is believed to be controlled by the temperatures in the contact zone, and in order to treat these in a quantitative manner the flash-temperature theory of Blok has been applied to cam and tappet systems. For this purpose, some preliminary measurements have been made of the coefficient of friction between cam and tappet.

Temperatures in the contact between cam and tappet reach maxima at three positions in the valve operating cycle, i.e., at the nose contact and at the two positions of zero tappet acceleration. These maxima probably increase continuously as engine speed increases, their relative values depending on the detailed design of the valve train, including the materials of construction of the cam and the tappet. If these temperatures are excessive, either scuffing or polishing wear is liable to occur, depending on the properties of the surfaces and of the lubricant.

A case of polishing wear is examined, and it is shown that most of the observed details may be explained on the flash-temperature theory. It seems necessary to postulate that a steel surface with a low velocity relative to a rubbing contact will scuff if the contact temperatures are high enough, but that the surface will become more liable to fail by polishing wear as this relative velocity increases. This is related to some phenomena observed with steel spur gears.

With certain limitations, the flash-temperature theory can be used to calculate the relative propensity to

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scuffing or polishing of different cam profiles, and a design giving a high positive acceleration and low negative acceleration is indicated. The cam nose radius should be between 40 and 50% of the maximum negative acceleration, expressed in units of length per camshaft radian squared. Reduction in bulk metal temperatures, reduction in the amplitude of the vibrations induced in the valve train, the use of progressive-rate valve springs, and an increase in the spherical radius of the tappet face could also help, where these steps are feasible. It should, however, be emphasised that these design indications to avoid scuffing have not been tested experimentally.

The Practicability of Establishing Threshold Values to Eliminate Stress-Corrosion Failures

By H. Suss

From *Corrosion*, U.S.A., Vol. 17, No. 2, February 1961, pp. 83–88, 11 illustrations.

Considerable basic research and experimental work have been done in the last fifteen to twenty years to obtain a better understanding of the stress-corrosion-cracking mechanism of metals. Work also has been carried out to determine the various factors which could contribute to a better understanding of stress-corrosion phenomena.

It should be noted that there is a wide variation in the test methods used to evaluate the stress-corrosion properties of metals and alloys. These tests have been carried out using U-bends, various modifications of bent beam specimens, or specially designed specimens to which stresses are applied by direct loading. The test specimens are exposed to simulated or accelerated types of corrosive media by localized wetting, partial immersion, total immersion, or alternate wetting or drying. However, it must be appreciated that there does not appear to be any universally acceptable stress-corrosion test method at present available.

This article reviews the significance of many factors which could affect the stress-corrosion behaviour of materials. These factors include the method of testing, variations normally present in the materials conforming to the same specification, slight variations in the test environment or metallurgical structure of the metal, accelerated corrosion attack (galvanic or crevice), residual stress, and the nature of corrosion attack. Based on this review, it is evident that all the factors do not act independently; instead, there is a complex mutual interaction.

As a result of these factors, it has been concluded that the stress-corrosion problem cannot be entirely eliminated at this time through control of specific parameters to establish threshold values. The recommended approach is selection of an alternate resistant material. Other approaches to minimize the problem are proper design, reduction of the corrosivity of the environment, reduction of effective stress, or the use of a protective layer. Evaluation under actual service conditions is an essential requirement. The possible danger of localized failure or increasing porosity of a protective layer with continued exposure of the base metal is also emphasised.

The Influence of Rate of Strain-Hardening in Machining

By P. L. B. Oxley, A. G. Humphreys, and A. Larizadeh

From a paper presented at a meeting of *The Institution of Mechanical Engineers*, London, April 18, 1961, 13 pages, 9 illustrations.

In analysing the metal-cutting process, it is usual to consider the relatively simple case of orthogonal cutting with a continuous chip. In orthogonal cutting, a layer of material (after removal termed the chip) is removed by a tool which has a relative motion parallel to the machined surface and perpendicular to its own cutting edge. Under many conditions of cutting, the continuous chip, which, as its name implies, is formed by continuous plastic deformation as opposed to rupture, is accompanied by a zone of highly deformed material, i.e., the built-up edge, which welds itself to the cutting edge of the tool. Because of the characteristic building up and breaking down of this edge, its presence makes the process non-steady and, in view of this and the related complications, it is usual to limit attention to the continuous chip without a built-up edge.

In order to determine the influence of the rate of strain-hardening (i.e., the rate of increase of flow stress with straining) on the machining process, cutting tests, as described in this paper, were carried out on a material with a high rate of strain-hardening and on a material with a relatively low rate of strain-hardening. All external parameters of the process (such as cutting force, chip-thickness ratio, angle of tool-chip interface friction, etc.) were measured, and a slip-line analysis of the plastic zone was made, using strain-hardening slip-line theory. The conclusions derived from these tests can be summarized as follows:—

(1) The difference in strain-hardening properties was not reflected in the external parameters of the process (cutting force, chip-thickness ratio, etc.), but the plastic zones were distinctly different. For the higher rate of strain-hardening material the plastic zone was wider, thus compensating for the relatively large change in maximum shear stress and giving a stress distribution and cutting force sensibly the same as for the lower rate.

(2) There was a striking agreement between the values of stress-strain slope and initial yield stress found using the strain-hardening analysis and the corresponding values measured from an independently obtained stress-strain curve of the machined material, and it appears that strain-hardening must be taken into account if a consistent theory of cutting is to be found.

(3) The line of action of the resultant cutting force was nearer the cutting edge than predicted by elastic flattening, and the contact between chip and tool extended from near the cutting edge to the point where the chip curled away from the tool.

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New Materials, Processes, and Equipment

Non-Inclinable Power Presses

A new range of Bentley non-inclinable presses has been introduced by Samuel Griffiths (Willenhall) Ltd. Of these, the 6-hp, 60-ton model provides 50 strokes per minute, has a fixed stroke up to 6 in. maximum and 18 in. daylight on top dead centre, the table area being 20 × 24 in., with a bed aperture of 12½ in. diameter. Another model in the range is a 10-hp, 100-ton press which provides 40 strokes per minute, and has a fixed stroke up to 8 in. maximum and 22 in. daylight on top dead centre, the table measuring 26 × 32 in., with a bed-aperture diameter of 15¼ in. A 200-ton model is also available.

Control of ram movement is effected by a multi-plate adjustable clutch and brake, and can be either hand-operated or foot-operated. A selector switch provides alternative control of the clutch only (with the motor isolated) and inching for tool-setting, or operation by single, repeat, or continuous strokes. The frame of the machine is fabricated from steel plates and is so designed that no weld is in tension or shear. The four long guideways are located at the corners of the ram, thus permitting intricate tools and dies to be accommodated.

Automatic Price-Computing Shop Scale

Although price-computing scales for the retail trade are not inherently new, rising prices and the increasing variety of goods sold and their price per pound have incurred design difficulties, principally in connection with size. The new "Aristocrat" scale (Fig. 1) announced by W. & T. Avery Ltd., of Birmingham 40, overcomes this

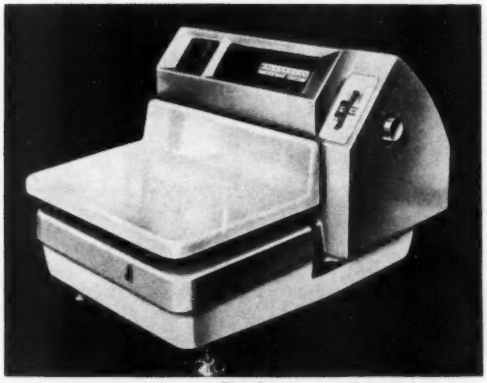

Fig. 1.

difficulty completely and, despite the fact that it enables 109 different prices per pound to be selected (i.e., more than double the number previously available with any scale in the U.K.), it is a low and compact unit, with overall dimensions of about 18½ × 23 × 16½ in. high. At the same time, it has a weighing capacity of up to 20 lb, with a sensitivity of 1 dram, providing within two or three seconds accurate indications of weight and computed total price for the selected price per pound on large, easily read illuminated viewing screens. These indications, together with an illuminated indication of the price per pound, are shown on the retailer's side of the scale and also on the customer's side, as can be seen in Fig. 2. In this way, faster and more accurate indications of weight and price can be made even by inexperienced assistants, with complete elimination of the usual "guess-work" associated with the price of odd ounces or fractions of an ounce.

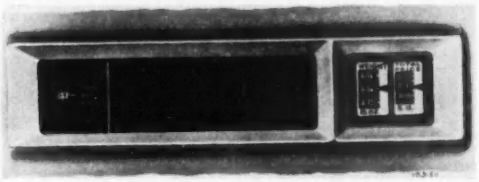

Fig. 2.

The heart of the new scale is an adaptation of the well-known "Microdot" process for producing extremely small photographic reproductions, making it possible to reproduce more than 400,000 characters on a glass disc, only 8 in. in diameter, in the body of the scale. These microscopic characters are then projected by a precision optical system, magnified by from 14 to 24 diameters, and optically split into two pairs of images, one on either side of the scale. Two projection lamps are provided, one being a spare. Should a lamp fail after prolonged use, movement of an easily accessible carriage puts the spare lamp into position for immediate operation.

To select the price per pound, a price-selecting drum is rotated to the desired price. To facilitate price-setting, a pilot chart (the horizontal scale in Fig. 1), on the retailer's side only, makes it possible to set up the required price per pound approximately before setting up accurately the price on the selector drum itself. For prepacking, a special taring device, with a capacity up to 1 lb, compensates for the weight of containers and packing without the need for making calculations.

Automatic Cutter-Grinding Head for Surface Grinders

An automatic cutter-grinding head for mounting on their Model 540 surface grinder has recently been developed by A. A. Jones & Shipman Ltd., of Leicester, and now makes it possible for cutters previously sharpened by laborious hand-feed methods to be ground with predetermined accuracy and no operator fatigue. Operation of the head is fully automatic, the indexing mechanism being operated by the table traverse and the down-feed applied automatically.

A general view of the Model 540 surface grinder arranged to take the new head is shown in Fig. 1. The machine is equipped with the standard down-feed unit fitted with a special screw-and-worm gearing, so as to give a down-feed range of 0·0003 to 0·0015 in., instead of the normal feed range of 0·0001 to 0·0005 in., one

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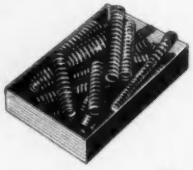

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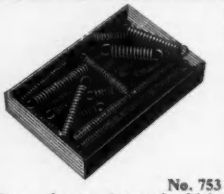

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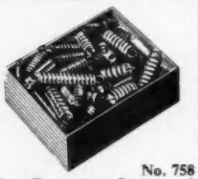

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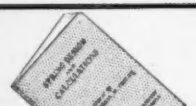

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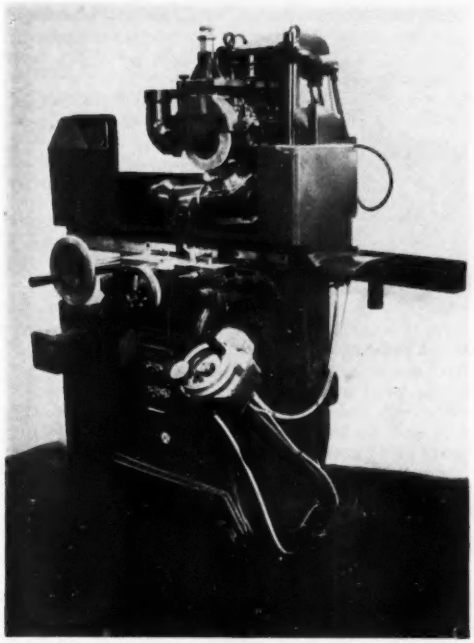

Fig. 1.

revolution of the handwheel giving a feed of 0·06 in., as compared with the standard feed of 0·02 in. In operation, the cutter spindle actuates a limit-switch on the head once per revolution, applying the down-feed by energizing a solenoid-operated valve in the down-feed hydraulic circuit. The down-feed unit applies the feed in preset increments until stopped by an adjustable trip mechanism on the column. When down-feed has ceased and a sufficient spark-out period has elapsed, the table traverse is stopped manually. The grinding wheel used is 8 in. in diameter. To ensure complete stability, a saddle lock is fitted, as well as an adjustable safety stop on the forward traverse on the table to prevent the table from being accidentally traversed past the reversing dog and running the grinding wheel into the opposite side of the cutter.

A close-up of the cutter-grinding head is shown in Fig. 2. In this instance, the attachment has been

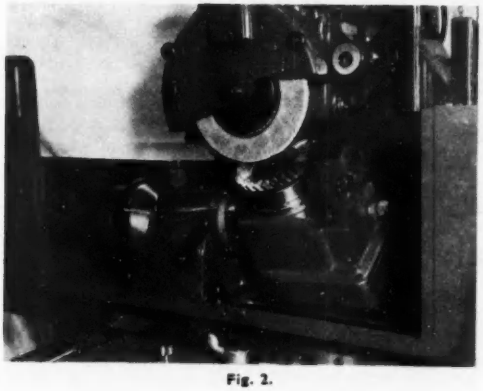

Fig. 2.

specially designed to sharpen circular gear cutters with varying numbers of teeth and a fixed top rake of 5 deg. normal to the helix angle. Both left-hand and right-hand cutters can be accommodated. The bracket carrying the cutter-head spindle can be rotated up to 40 deg. each side of the zero position for both left-hand and right-hand cutters. An indexing ring is provided for registering the angular setting of the bracket, which is locked in position by a clamping lever. Separate locating pieces are provided for setting the cutter in the grinding position on the spindle, the cutter being locked at the correct setting by a clamp screw.

The indexing principles employed necessitate the full traverse stroke being maintained at all times, to ensure that the mechanism functions correctly. Interchangeable indexing discs, carried at the lower end of the cutter spindle, are provided. The indexing disc engages a spring-loaded V-point lever which automatically locks the spindle as the attachment passes under the wheel, control of indexing accuracy being effected solely by means of the indexing disc and V-point lever.

High-Frequency Condenser-Discharge Ignition System

A new ignition system, claimed to meet all the major problems of the two-stroke engine, is announced by Wipac Group Sales Ltd., of Buckingham. The system, known as the "Magister", employs a high-frequency condenser-discharge principle with a high spark rate, reducing the familiar causes of two-stroke failure, the most common being erratic fuel/oil ratio with consequent starting difficulties. Also, the problem of ignition failure caused by excess oil or dirt on the contact-breaker is overcome by the mechanical advantage of employing the closure of the contact points to produce the spark. Although the principle of condenser discharge is not new, previous systems have proved to be too expensive to produce on a mass scale. The new system is, however, economically practical, with the added advantage of being suitable for use with the standard sparking-plug, instead of the expensive surface-discharge type found necessary with past systems.

The "Magister" system differs from the conventional method of magneto ignition in that the usual high-tension ignition coil is replaced by a feed coil. Alternating current, induced from the feed coil in the same way as in conventional systems, is then converted to direct current through a small rectifier which, in turn, charges a condenser. The charge is retained by the condenser until the contact-breaker closes, when the stored current is discharged through an ignition coil, which again uses primary and secondary windings, producing a high voltage that is taken to the sparking-plug by a high-tension lead.

Producing the spark during closure of the contact-breaker shows distinct advantages. Thus, when the spark is produced at the time of opening, the arc forme by the current is extended over a period, whereas, when the contacts are closed at the time of sparking, the condenser discharge rate is of a much higher order, with a reduction in arcing, resulting in an appreciable increase in point life. Also, with the conventional magneto, the breaking of the contact points to the magnetic break is of utmost importance. With the "Magister" discharge system, however, this timing is not so critical, and any discrepancies at this point have little or no effect on the ignition output, because the condenser holds its charge

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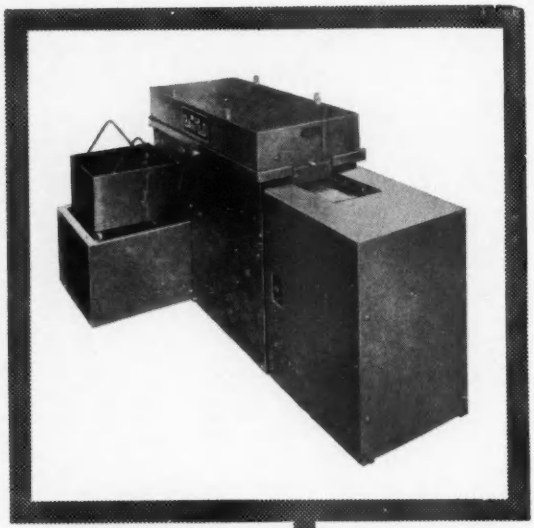

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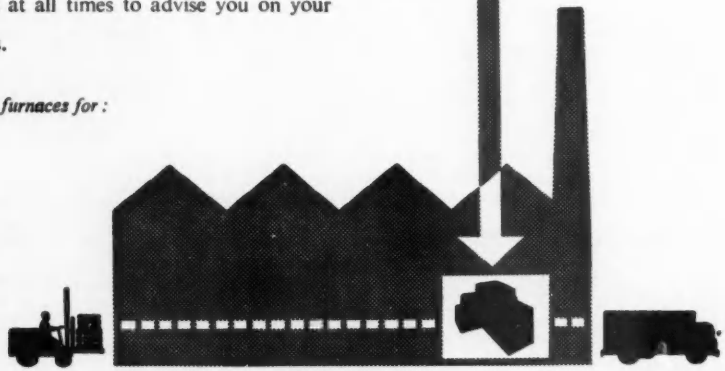

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from the feed coil till the contact-breaker closes. While a recommended contact clearance is given, variations from this do not affect the magneto output.

Tests with a wide variety of engines have shown that the initial rate of burning achieved with the new system makes it necessary to retard the ignition by 3 to 4 deg, indicating that the firing of the mixture in the combustion chamber is initially of a higher flame rate than with the conventional system. This retarding effect still provides optimum power from the engine. In addition, it has been found possible to use fuel/oil ratios previously considered non-combustible, e.g., a 4 : 1 petrol/oil ratio in a 24 : 1 two-stroke engine. While maximum power is not claimed using such a ratio, starting and running, even at low speeds, is not affected.

Other tests designed to subject the engine to conditions of extreme misuse included throwing dust and oil between the contact-breaker points, pouring water over the sparking-plug, smearing the plug in sump oil and dirt, and inducing oil at the air intake. The engine started and continued firing throughout all these tests. The "Magister" system is particularly suitable for marine applications, e.g., outboard motors, as the electrical circuit is not so susceptible to water. Similarly, it is less affected by conditions of extreme humidity and dust, particularly prevalent in agricultural and horticultural applications.

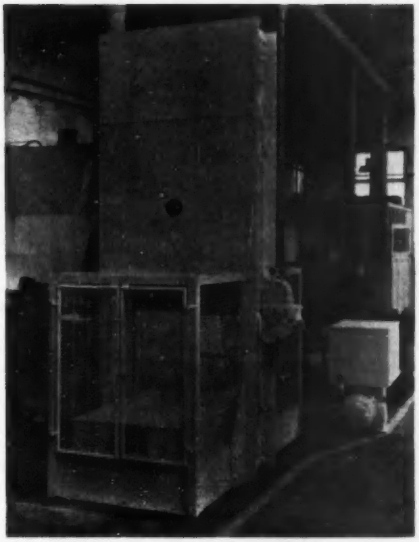
While the advantages of the system are not so pronounced for four-stroke engines, experience has shown that it is possible to use varying grades of fuel on a standard four-stroke petrol engine with no special adjustment to the carburettor or ignition timing. Changes of fuel types can be made after only a very short warm-up period with no noticeable reduction in power.

Machines for Splitting Bales of Raw Rubber

A range of machines introduced by Sutcliffe Hydraulics Ltd., of Whitwood, Castleford, Yorks., is designed to split up bales of raw rubber, the equipment essentially comprising a down-stroking press with a table on which the bale is placed and a blade, in place of the usual top die. The standard single-bladed machine is capable of splitting bales up to 27 in. in width, 36 in. in length, and 21 in. in height, but other sizes are also available, including a two-bladed machine to meet special requirements.

The machine consists of a baseplate, on each side of which large rolled-steel channels are bolted to form two columns tied together at the top by a strong bridge constructed of rolled-steel joists welded together. On the underside of the top bridge are positioned several double-acting hydraulic rams and a blade made of 1-in. mild-steel plate fitted to the lower end of the rams. The blade, which is held in guides attached to the columns, is provided with a renewable cutting edge. To move the bale under the blade, a traversing table is fitted to the baseplate, the table being traversed by a hydraulic cylinder. The columns and blade cylinders are encased in sheet-metal guards, while mesh-type guards are provided over the traversing table.

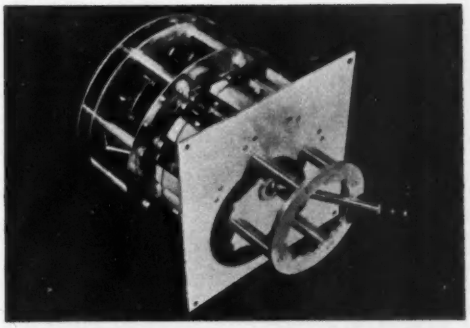
The hydraulic cylinders for raising and lowering the blade are banked together and are fed from one control valve, which is itself banked together with the valve used to control the traversing table. Common supply and return mains are taken from the control valves to a power-pack consisting of a fixed-delivery pump coupled to an electric motor, both of which are flange-mounted



to a stool that acts as a baseplate, coupling guard, and support for the oil tank. A filter is fitted in the tank, and an adjustable relief valve is incorporated for varying the pressure, if necessary.

Joystick-Type Selector Switches for Furnace Control

Eliminating relays and complicated electrical interlocks by means of a simple mechanical joystick type of control, a new range of selector switches for furnace control has been developed by the Pye Switch Division of Pye Ltd., of Burgess Hill, Sussex.



Different furnace heats are selected by moving the lever in a rotary and clockwise direction, a mechanical interlocking system being incorporated to prevent the lever from inadvertently being moved backwards in an anti-clockwise direction or forwards through more than one heat-selection position at a time. It is, however, possible to arrange interlocking in such a way that the operator can move the control backwards and forwards through a predetermined number of positions, in order to permit adjustment of the heat cycle over a given part of the range. This particular unit has eight switching positions, incorporating both single-pole and double-pole switching.

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Dave Davies and Les Brown head the Birfield-Hilco oil filtration team—the only one of its kind and calibre in Britain.

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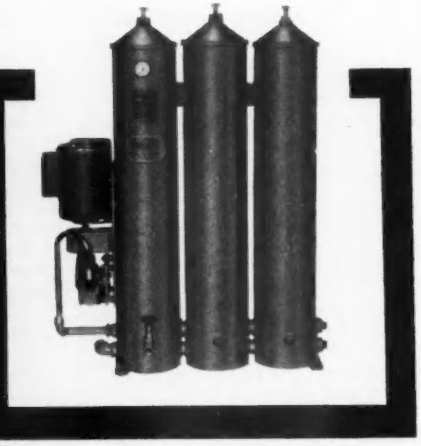

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ENGINEERING, MARINE, WELDING, AND NUCLEAR ENERGY EXHIBITION

In our April issue, we described some of the range of products shown at the Engineering, Marine, Welding, and Nuclear Energy Exhibition, which was held at Olympia, London, between April 20 and May 4, 1961. In the following pages, details are given of a further selection of exhibits.

Smiths Industrial Division

In addition to high-speed pen-recording equipment and a new panel for the automatic protection of internal combustion engines, Smiths Industrial Division exhibited two examples of their range of ultrasonic flaw-detection equipment. Of these, the Mark-6 equipment is a powerful and versatile instrument designed for routine inspection and for laboratory investigations into the transmission characteristics of metals. Special design features include a wide range of operating frequency, a calibrated time base, delay, and markers, stabilized power circuits, and display on a 5-in. cathode-ray tube. The equipment operates with barium titanate probes having single, twin, or separate transmitter and receiver heads, and is suitable for contact, gap, or immersion scanning techniques. Additional monitoring circuits can be incorporated to permit the use of semi-automatic inspection methods, while provision is also made for photographic recording of the cathode-ray tube. A specially designed trolley incorporates an adjustable cradle which permits the display and control units to be positioned at a convenient angle for operation and viewing.

The second flaw-detection unit is the Mark 5F, which is a multi-frequency instrument specially designed for production testing and laboratory investigations where the applications involved can be met adequately by the use of probes having twin or common transmitter/receiver transducers. The instrument, which is of light-weight construction and is readily portable, provides a well-defined trace, readily visible under normal conditions of ambient light and extending over the full width of a 3-in. cathode-ray tube. The frequency range is from 625 to 5000 kcs, while a 10-position switch gives metal-thickness ranges from 2 in. to 12 ft in mild steel, though an additional position for examination of thicknesses up to 25 ft can be incorporated to special order. A fine range control ensures adequate overlap of individual range settings.

Both these instruments can be used in conjunction with the Kelvin Hughes two-channel flaw alarm, which has been specially designed for use with Kelvin Hughes ultrasonic flaw detectors to facilitate the use of semi-automatic inspection techniques, thereby removing the onus of signal discrimination from the operator, as defects within the selected range of discrimination are immediately and automatically identified and indicated either visually or audibly. This equipment permits the simultaneous examination of two independent regions in the material under test, automatic indication of defects, and independent adjustment of depth position and degree of sensitivity within each region under inspection. The search region is shown on the cathode-ray tube as a brightened section of the trace, the position and width of which can be varied continuously over three ranges to give coverage from 2·5 to 3500 microseconds, and which can be positioned to overlap, either partially or completely, thereby permitting a portion of the whole cross-section of the material to be examined at two levels of sensitivity, each of which can be adjusted independently.

The Coventry Victor Motor Co. Ltd.

In addition to a comprehensive range of air-cooled and water-cooled petrol engines and diesel engines, with and without "Perfecta" and "Victor-Hydraulic" forward/reduction/reverse gearboxes, The Coventry Victor Motor Co. Ltd., of Coventry, displayed three new engine sets, i.e., an H.D.A. diesel engine with welding, cutting, power, and lighting equipment, an A.D.3 diesel engine with a "Victor-Warwick" pump, and an A.D.3 diesel engine with a flange-mounted 3·5-kVA alternator.

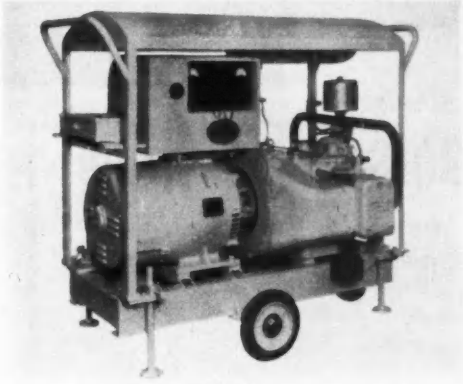
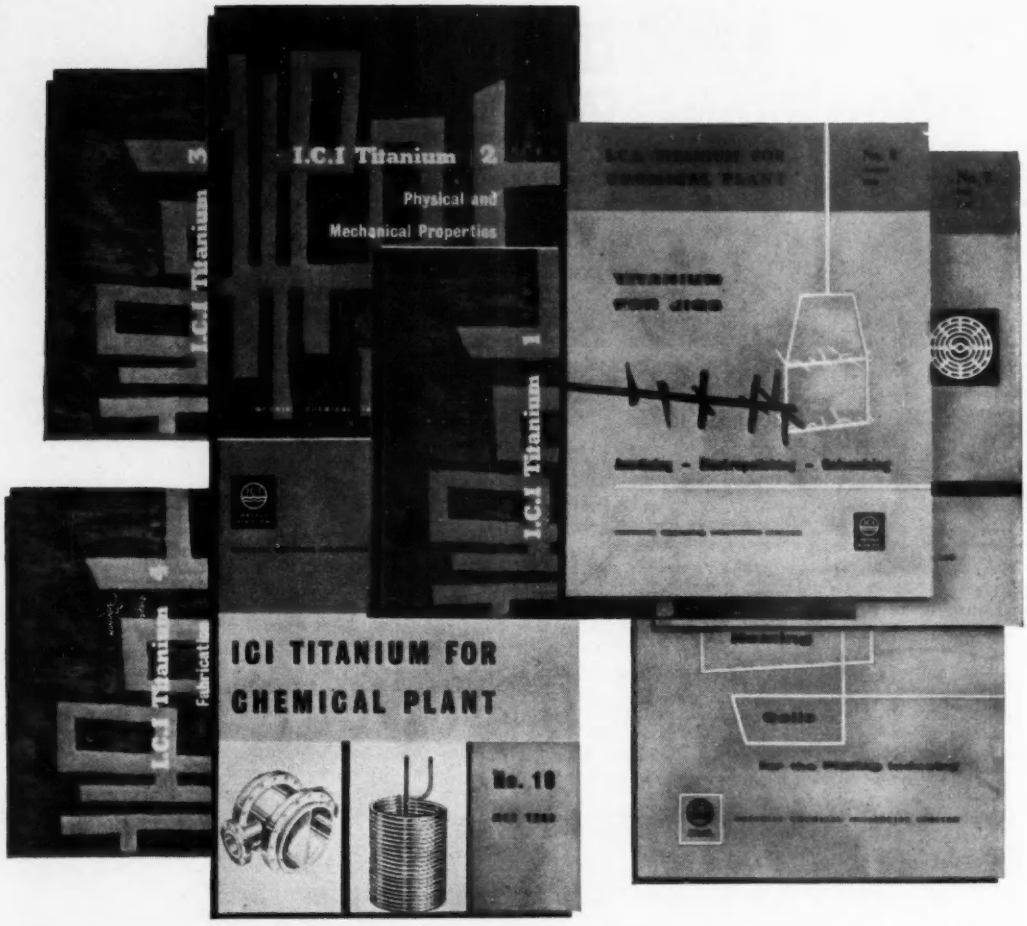


Fig. 1.

The H.D.A. set (Fig. 1) has an air-cooled, horizontally opposed, twin-cylinder, compact multi-purpose engine of 14/20 bhp, and is specially useful where repair and constructional work has to be carried out at remote locations and where initial supplies of electrical power are not available. The set has an output of 240 V, 50 cps (or 110 V, 50 cps, if required to comply with certain regulations) and is equipped with Class-A insulation and radio interference suppressors. The power side can be



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used for small tools, hammers, etc. and, when arc-welding or cutting operations are in progress, provision is made for a wander-light to illuminate the work. The capacity of the set (175 A) ensures ample power for welding or cutting operations, while tappings at lower amperages make it possible to deal with the lightest work. The set, which is trolley-mounted and can be transported with ease, has a nett weight of approximately 1025 lb.

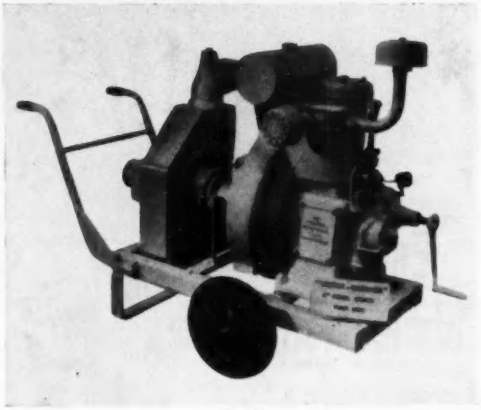


Fig. 2.

The pumping unit (Fig. 2) comprises an A.D.3 air-cooled single-cylinder diesel engine, rated at 5/8 bhp and a "Victor-Warwick" 4-in. self-priming pump, the whole unit being of compact design and trolley-mounted on a substantial framework with rubber tyres, making it easily manageable by one operator. This set, which has a nett weight of just over 900 lb, has been designed to meet the requirements for a lightweight utility pumping unit, the maximum capacity being 400 gpm, or 50 gpm with a head of 80 ft. Priming is automatic up to 25 ft by means of a recirculation device, which is self-cleaning and has an automatic cut-off, without the need for valves or levers.

The alternator set consists of an A.D.3 diesel engine and a single-phase alternator in unit construction, close-coupled by a stubshaft and a flexible-coupling drive, the whole unit being mounted on a fabricated-steel light-weight underframe with facilities for foundation bolts. The unit, which has a nett weight of about 530 lb, is of unusually compact design, and the close-coupling arrangement through the flexible coupling has the additional advantage that the simplified bedplate used takes up much less room, with a consequent saving in weight, than a direct-coupled set. The output of the 240-V generator is 3·5 kVA at a frequency of 50 cps, or 4 kVA at a frequency of 60 cps.

Crofts (Engineers) Ltd.

A comprehensive range of power-transmission equipment exhibited by Crofts (Engineers) Ltd., of Bradford, Yorks., included a new size (1·33-in. centres) of the "Par-O-Mount" worm reduction gear, which is now designed for universal mounting. In addition, a 3-in. centres gear of this type was shown sectioned, to demonstrate an integral backstop and to illustrate its ready convertibility to right-angled variable-speed drives. Also shown was a special worm reduction gear designed for agitators, with a large-flanged output shaft and bearings for handling the heavy loads in an application of this type, as well as a new metric range of shaft-mounted. gears, offering 5 : 1, 15 : 1, and 20 : 1 nominal ratios. This new range is interchangeable with the existing series and can incorporate the same backstops and make-up bushes; size for size, it has the same power rating.

Other exhibits included a Crofts variable-speed motor unit for infinitely variable high output speeds, either for direct coupling or by means of a V-drive or a "Power-grip" drive. A version of this unit was also shown combined with a multi-speed gearbox (of which two-, three-, and four-speed types are available), making it possible to increase the range of infinitely variable output speeds offered. Another variable-speed gear shown was the horizontal-type "Klosed", which is of improved design and incorporates centralized lubrication and other advantages. Sliding surfaces are specially treated before assembly to prevent sticking in operation.

Also exhibited were a "Ritespeed" conveyor pulley (a compact unit with gearing incorporated in the barrel and occupying little floor space), a special worm-geared motor unit with V-rolls keyed for conveying tubes, and a combination of the well-known "Croft-Ring" and an internal gear half-coupling, to show the very considerable torsional flexibility that can be achieved, permitting greater parallel and angular misalignment.

John Bull Rubber Co. Ltd.

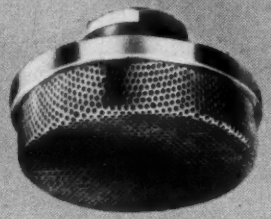
Engineering components, such as silent gearwheels, conveyor pads, diaphragms, rollers, and hammer heads made of "Prescollan", which is a polyurethane rubber with exceptional resistance to tearing, abrasion and, impact and, in the harder grades, combines the advantages of rubber and plastics, were featured by the John Bull Rubber Co. Ltd., of Leicester.

In addition to components made of "Prescollan", the company exhibited a wide range of products in natural and synthetic rubber for railway, electrical, chemical, and general engineering, including convoluted and shaped hoses, air-cooling, steam-heating, and brake hose, traction-motor ventilating bellows, and mouldings of nearly every description.

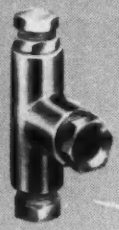
Carter Gears Ltd.

Exhibits from Carter Gears Ltd., of Bradford, Yorks., included working and static exhibits representative of their range of units from fractional-horsepower to 40 hp in Carter Gear control arrangements, and complete Carter

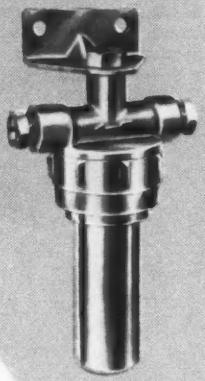
Fig. 3.



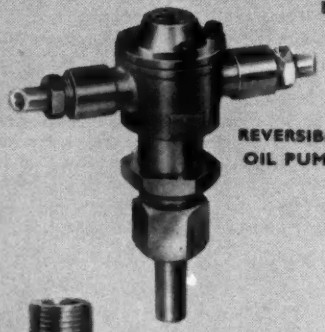
OIL STRAINERS



OIL PRESSURE RELIEF VALVES



OIL FILTERS



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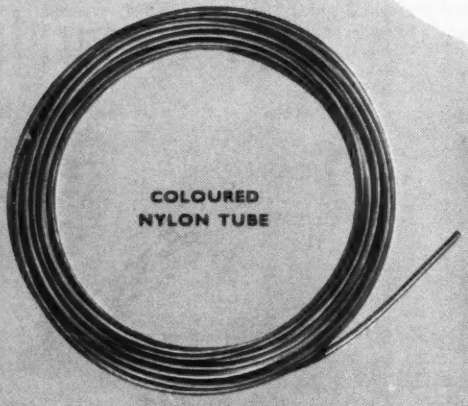

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variable-speed drives, including reduction gears and drive motors.

Two new additions to the existing range of Carter hydraulic variable-speed gears were also featured, these being the restyled Size F10 Carter Gear, two of which were shown to illustrate the advantages of the modified external design when fitting auxiliary equipment such as drive motors and control gear, and the new 10-hp Size AM26 gear. This latter gear, shown in Fig. 3, is similar in design to the well-known "A"-type Carter gears and incorporates the patented original torque-sharing positive-displacement hydro-mechanical design.

Thos. Firth & John Brown Ltd.

Exhibits from Thos. Firth & John Brown Ltd., of Sheffield, were selected to illustrate a representative range of their products, including carbon-steel and alloy-steel forgings for marine turbines, transmission gears, and power generation, forged-steel cylinders, rings, and other forgings for aircraft, gas-turbine and jet-propulsion units, and forged-steel die blocks.

Forged-steel rolls made by the company for the rolling of ferrous and non-ferrous sheet and strip, precious metals, plastics, etc., are supplied in the fully hardened condition up to 36 in. in diameter and 17½ tons in weight, and back-up rolls up to 56 in. in diameter and 45 tons in weight. Rolled-steel products are available in the form of black and bright bars for highly stressed parts in the aircraft, motor, and general engineering industries. The company also specializes in the manufacture of high-grade steel castings for heavy-duty wear, especially in the quarry, cement, and associated industries.

E.N.V. Engineering Co. Ltd.

Exhibits by the E.N.V. Engineering Co. Ltd., of London, N.W.10, included examples of straight-tooth bevel and hypoid gears in sizes from 1-in. diameter, and examples of precision spiral bevel gears with profile-ground teeth. Examples of transmission and final-drive gears, mainly for battery, electric, and industrial trucks and special-purpose vehicles, included double-reduction axles and differential carrier assemblies, transmission gears, and gearboxes, as well as a new double-reduction-differential carrier assembly, designated the D.R.129, which is available for overall reduction ratios up to 19 : 1 and with an output-torque capacity of about 5000 lb-ft.

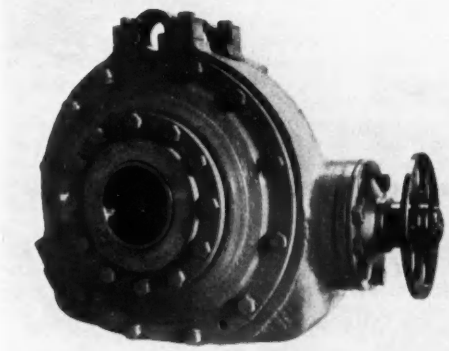

Fig. 4.

Exhibits of rail-traction gears included a hypoid axle-mounted drive unit for electric and diesel rail-cars (Fig. 4), spiral bevel gears for shunting and main-line locomotives, and precision spiral bevel gears with ground teeth, as used for a gas-turbine locomotive. Marine gears included narrow-angle V-drive spiral bevel gears with profile-ground teeth, as used for high-speed marine-propulsion drives for power units up to 4000 shp, and also the well-known ENV drive for use with engines up to about 100 hp. This drive has a 16-deg. shaft angle and incorporates spiral bevel gears.

Other exhibits included examples of spur and helical gears, straight-tooth bevel, spiral bevel, and hypoid gears for a variety of industrial applications. Of particular interest was a pair of hypoid gears in hardened alloy steel, with a 6-in. offset and a wheel diameter of 40 in., believed to be the largest hypoid gears manufactured in the U.K.

The General Electric Co. Ltd.

Devoted entirely to marine equipment, exhibits by The General Electric Co. Ltd., of London, W.C.2, included examples of the company's well-known luminous-indicator fire-alarm equipment, as installed on many passenger liners during the past twenty years, luminous call systems for cabin stewards, double-oven galley equipment, stainless-steel marine water boilers, and hot-cathode fluorescent-lighting fittings for use in accommodation spaces, alleyways, promenade decks, saloons, and messes.

Exhibits of switchgear included new additions to the "Mutac Clipper" range of 250-V a.c. switches and accessories, only three sizes of box being necessary to give a range of from 1- to 12-gang switches. Also included was a selection of "Cromwell" switch-fuses and fuse-switches (a development of the well-known "MW" range), produced in ratings up to 400 A, 500 V, as well as examples of "Hidutac" switch-fuses, which are capable of unlimited full-load switching and are available in ratings of 440 V a.c., 15 A, 30 A, and 60 A, with either H.R.C. or semi-enclosed rewireable fuses.

An item of special interest was an improved type of lifelight for attachment to rafts, lifeboats, and lifebuoys. This light is operated automatically by a mercury switch and has a built-in safety device to prevent accidental switching while it is in the stowed position. The lifelight, which has been approved by the Ministry of Transport, is also suitable for use on tankers, and is fed by dry cells, enabling the lamp to burn continuously for 20 hours.

David Brown Industries Limited

As was only to be expected, exhibits from David Brown Industries Ltd. were representative of the company's wide range of interests, from gear-cutting tools and floating reamers to bronze and steel castings, gears, pumps, and speed reducers. Of the latter, the "Varicon" infinitely variable speed reducer was well represented, as also was the new range of David Brown "Radicon" worm reducers, two basic types being covered, i.e., the "Adaptable", spanning the range from 1⅛ to 3⅛ in. gear centres, and the "Solid Foot", ranging from 4 to 8 in. centres. The main features of this new range are the substantially higher thermal and mechanical ratings of the units, and the incorporation for the first time of fan-cooling in the small "Adaptable" units.

Of the general range of gearing exhibited, particular interest attaches to a set of synchronizing gears for

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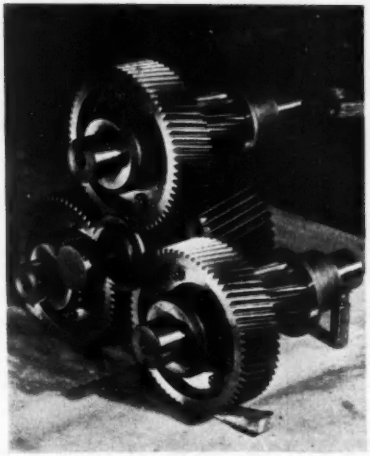

Fig. 5

British Railways 2300-hp diesel locomotives. These spur gears are supplied by the David Brown Gear Division, of Huddersfield, to Vickers-Armstrongs Ltd., who manufacture under contract to Sulzer Bros. (London) Ltd.

As an example of David Brown achievement in the development of high-speed gearing for turbine drives, a three-layshaft coaxial helical unit was also exhibited. This unit (Fig. 5) is typical of the multi-layshaft designs, developed to meet the high ratios involved in turbine drives while still keeping peripheral velocities down to reasonable proportions. Of extremely compact design, this type of unit effects a considerable weight and space saving, compared with conventional side-by-side units. Since the input and output shafts have no transverse forces acting on them, there is no need for the provision of a high-speed bearing. The low-speed bearing, which normally carries the weight of the gear assembly and acts as a location bearing can, if required, be used to support one end of an adjacent unit, such as a generator armature. The example shown was a three-layshaft unit as supplied to Ruston & Hornsby Ltd. for driving a turbo-alternator. This unit is required to transmit 1200 hp, reducing the speed from 13,000 to 1800 rpm.

Of the pump exhibits, of special interest was a double-volute centrifugal pump of a type which has recently gone into production at the David Brown Foundries Division, Penistone, near Sheffield, and which has been introduced as the result of an agreement with the Bingham Pump Company, of Portland, Oregon, U.S.A. These pumps are of the horizontal single-stage type and are claimed to be unique in that the hydraulic pressure in the pump case is balanced at all diametrically opposite points around the periphery of the impeller throughout the operating range of the pump.

George Angus & Company Limited

The main exhibits of George Angus & Co. Ltd. were their range of hydraulic winches, which have been designed specifically for use in modern motor-driven fishing vessels. Available in a range of powers from 25 to 250 hp, these winches are powered by the Angus hydraulic transmission system, enabling them to be conveniently positioned without the restrictions normally imposed by conventional driving methods. Power to drive the winch can be derived either from the main engine of the vessel or from a separate auxiliary, while the hydraulic drive permits infinitely variable speed to be obtained in both haul and veer positions and gives exceptionally high pulls without the expenditure of excessive power. The controls can be preset to allow the winch to operate at a given pull, thus avoiding warp breakage, and this feature is further enhanced by a specially designed gear-train in the main drive. Because of the smooth load and speed characteristics, coupled with complete freedom from snatch, wear and tear of fishing gear is very considerably reduced.

Also exhibited was a range of standard double helical reduction units for transmitting up to 300 hp with high input speeds, and also a range of light geared motors, one of which (the "Ball-Drive" unit) is a novel, cheap, and efficient reduction motor without conventional gears.

Richardsons, Westgarth & Co. Ltd.

In association with **Atomic Power Constructions Ltd.**, the Richardsons Westgarth Group are supplying the whole of the generating, condensing, and feed-heating plants, as well as the carbon dioxide circulators, for the Trawsfynydd nuclear power station in North Wales. Exhibits by the company included a number of products developed for Trawsfynydd, e.g., an entirely new type of bellows restraint mechanism, a CO_2 blower rotor, and a scale-model cascade corner bend for the CO_2 circuit.

A special display was devoted to vacuum flash evaporators, which the Richardsons Westgarth Group pioneered in Great Britain, and included an animated flow chart of a typical Richardsons Westgarth evaporator. In addition, photographs and models of some of the different types of engines produced by the Marine Division of the Group were featured, including a model of a Götaverken engine (the 760/1500 VGS-U8), developing 10,000 bhp at 112 rpm, a model of the engine-room of the M.V. *Turakina*, showing a Clark Sulzer 8RD76 engine (10,400 bhp at 119 rpm) fitted with exhaust-gas turbo-blowers, and a model of the machinery section of a 40,000-ton tanker with Parsons Marine geared turbine propelling machinery (17,600 bhp at 108 rpm) and Richardsons Westgarth-Foster Wheeler water-tube boilers with a maximum evaporation of 200,000 lb/hr for steam conditions at the superheater outlet of 600 psig at 850°F.

The English Electric Co. Ltd.

A full range of arc-welding equipment, electrodes, and accessories, including hand shields of resin-bonded fibre, welding meters for measuring the electrical conditions in a welding arc in a.c. welding production, research, and development, and a range of ignitrons used as precision contactors in the control of resistance-welding equipment, were exhibited by the Welding Division of The English Electric Co. Ltd., of London, W.C.2.

Other exhibits included the LWAD and the LWC range of welding equipment. Of these, the LWAD equipment is unique in that it can give either an a.c. or d.c. output at the turn of a switch. Of compact design, these versatile units can be used for a wide variety of fabrication work, eliminating the cost and space of two separate sets. They are specially suitable for overseas operation in tropical and underdeveloped areas where trained maintenance engineers are at a premium, as the power source is static, containing no moving parts and therefore needing little maintenance, while their efficiency

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is high and they show considerable savings in overall costs, compared with conventional d.c. motor-generator equipment. The range of LWAD equipment is oil-cooled, while the silicon-diode rectifiers used are also oil-cooled and cannot be damaged by overheating. In fact, the units will operate satisfactorily at temperatures up to 190°C.

The LWC range of welding equipment is used where the installation of multi-operator plant is not justified. With this range of equipment, welding currents of 30 to 630 A can be obtained. One unit in the range contains two current regulators and can cater for two welders at 315 A each; alternatively, when occasional heavy-current welding is required, the outputs can be arranged in parallel to provide 630 A for one welder. As in the case of the LWAD range, the power source is static and the equipment is oil-cooled.

A wide range of electrodes was also featured, including iron-powder electrodes with a high rate of deposition, electrodes for the more rapid welding of stainless steel, all-position mild-steel electrodes, and electrodes for creep-resisting steels, for the vertical and overhead welding of mild steel, for heating before welding, bending, or straightening, and for grooving, gouging, and piercing.

The British Oxygen Co. Ltd.

A wide range of equipment was exhibited by The British Oxygen Co. Ltd., together with demonstrations of the latest techniques and advances in the production and distribution of industrial liquids and gases. Thus, for instance, how the constantly growing demand of industry for oxygen is being met was demonstrated by a model of an oxygen-producing plant, while the comprehensive service offered by the company for the supply of propane in bulk or in portable cylinders was also illustrated, together with displays representative of the bulk supply of oxygen, nitrogen, argon, and acetylene. In addition, a comprehensive range of Sievert air/propane heating equipment was displayed, as well as an example of the latest vacuum-insulated evaporator vessel, one of a range with air-heated vaporizers.

A wide range of hand equipment for cutting, welding, and heating, including the new "Firefly" lightweight hand-cutting blowpipe and its welding counterpart, the "Saffire", was also featured, together with a range of cutting machines. One of these is the latest "Bison" profile cutter, with a new automatic line-following device which eliminates templates, thereby saving time and costs. In addition, a new lightweight portable straight-line and circle cutting machine was shown, as well as the latest "Alyn" pipe-cutting machines for pipeline work and branch preparation.

In the field of welding, exhibits included a comprehensive display of argonarc welding products, among which were the latest argonarc transformer set, the ACR.150, and the new SW.300 spot-welding torch, which has been designed to be operated simply and cheaply by semi-skilled labour and with which spot welds can be made with one hand, access to only one side of a joint being required. Other welding products included a new lightweight 225-A generator, displayed in two forms, i.e., diesel-engine-driven and electrically driven, a ram-type welding boom and roller-bed installation, the portable "Sigmette" gun and control for non-ferrous welding, and a wide range of "Quasi-Arc" electrodes for all manual, semi-automatic, and automatic electric welding processes.

The latest advances in automatic welding included exhibits of the Mk.2 twin fillet welder fitted with two "Basic" heads, adaptable for "Fusarc/CO_2" "Fusemelt", "Unionmelt", or "Sigma" automatic processes. In addition, the new MRCS.300 slope-controlled rectifier for electric welding was featured. This unit, which is designed for semi-automatic welding, using the "short-circuiting arc" technique, is employed with "Lynx" equipment for welding mild and stainless steels, and was demonstrated with the new ST. torch, which has been designed particularly for "fine-wire" welding and which provides excellent accessibility and eliminates operator fatigue. The new rectifier also supplies power for the "Unionarc" electric welding process, which employs bare wire, gaseous carbon dioxide, and a magnetic powdered-flux shield.

W. H. Allen Sons & Co. Ltd.

Exhibits by W. H. Allen Sons & Co. Ltd. were representative of the wide range of Allen power-generating plant, pumping machinery, and electrical equipment, such as steam turbines, diesel engines, gas turbines, steam engines, centrifugal, mixed-flow, and axial-flow pumps, gearing, a.c. and d.c. generators and motors, and motor control gear for marine, industrial, and other services.

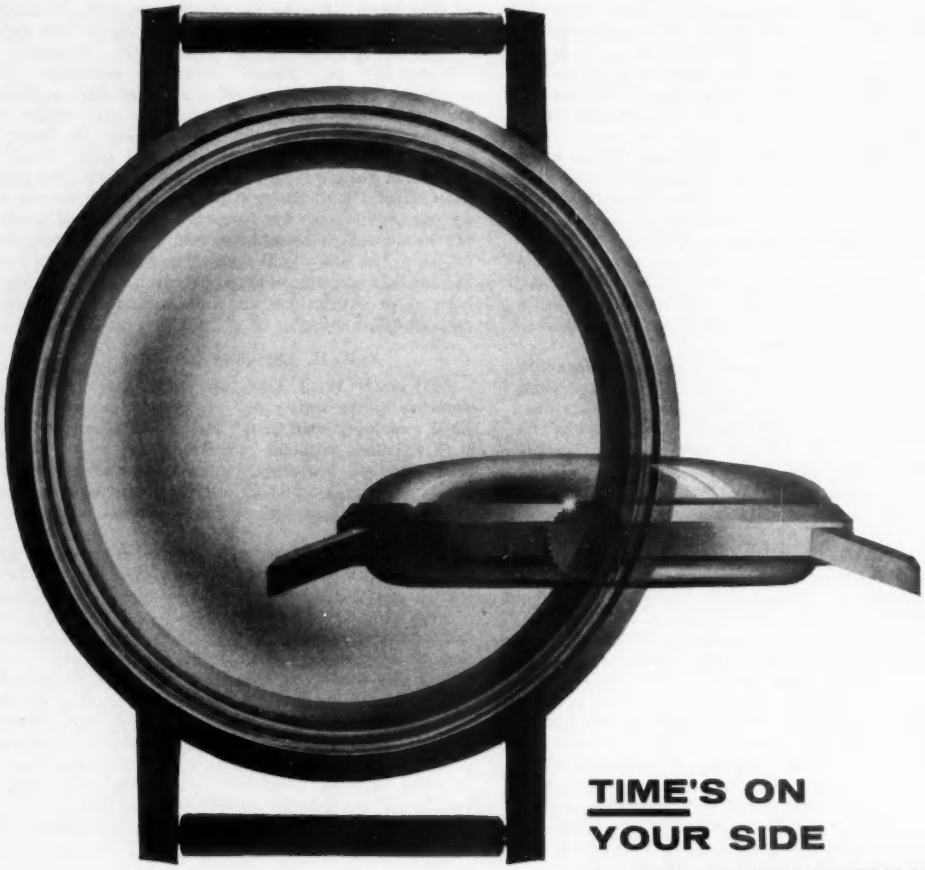
The largest exhibits were a 750-kW marine-type back-pressure turbo-alternator designed for tanker service, and a 250-kW diesel-alternator set, comprising a 5-cylinder, 428-rpm, 360-bhp dual-fuel engine and a self-regulating alternator, together with associated control equipment. The 750-kW turbo-alternator is one of two similar units for installation in a 37,000-ton tanker for the P. & O. group fleet, and comprises a turbine designed to operate at 13,500 rpm under steam conditions of 575 psig at 830°F, exhausting against a pressure of 20 psig, driving via a gear-type flexible coupling and an Allen-Stoeckicht planetary double-helical epicyclic gear the 750-kW, 440-V, 3-phase, 60-cps, 1800-rpm alternator, which, to meet the requirements of Lloyd's Register of Shipping, is capable of a 25% overload. Other electrical exhibits included a 550-kV brushless alternator with control equipment, a range of a.c. and d.c. motors, and motor starters.

Pump exhibits included a 15/12-in. horizontal, single-suction, two-stage pump for waterworks service and a working model of a two-bladed unchokeable sewage pump. Epicyclic gearing was represented by a unit incorporated in the turbo-alternator mentioned above, as well as by a 4000-hp speed-increasing planetary-type gear (1466/4549 rpm) for a power-station boiler feed-pump application and a 1150-hp speed-reducing planetary-type gear (980/180 rpm) for a pump application in a nuclear power station.

Imperial Chemical Industries Ltd.

Imperial Chemical Industries Ltd. were represented by two divisions, i.e., the Metals Division and the Billingham Division, and also by **Marston Excelsior Ltd.**, a subsidiary company of I.C.I., with exhibits covering nuclear engineering, titanium, heat exchangers and heat-exchange products, and general-engineering materials.

The nuclear-engineering section featured examples of zirconium, beryllium, hafnium, niobium, and other metals. "Boroplast", a boronized plastic material for use in radiation shields, was also included in the display, while Marston Excelsior Ltd. showed a wide variety of



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fabrications for nuclear-engineering purposes. With titanium, emphasis was on applications, rather than on wrought products, and included metal-finishing, as well as plant for the chemical industry and cathodic protection.

Included in the section devoted to heat exchangers and heat-exchange products, were a cross-section of an aluminium secondary surface heat exhanger, with models of a typical installation of units of this type, and "Integron" integral-finned "High-fin" and "Low-fin" forms in copper, copper-alloy, aluminium, and bi-metals for use in the electrical, petro-chemical, air-conditioning, and other industries, as well as roll-welded heat-transfer sheets in "Impalco" aluminium.

Exhibits in the general-engineering section included "Portolite" flexible tanks for the transport of liquids, a selection of "Marex" plastic laminated fans for fume removal from chemical equipment, a range of bursting discs in a variety of metals and other materials, and "Impalco" aluminium fish-pound boards, stanchions, and lorry-body sections.

The Billingham Division featured the uses of both liquid and solid carbon dioxide in industry, the central exhibit being an I.C.I. standard 5-ton storage tank for liquid carbon dioxide. Also displayed was a "Drikold" CO_2 liquefier and examples of "Drikold" as a refrigerant. The use of I.C.I. carbon dioxide for shrink-fitting, rubber deflashing, welding, and the CO_2/silicate process were illustrated on panels, and the prominent role of the company in supplying the nuclear-energy industry with liquid carbon dioxide was also stressed.

G. A. Harvey & Co. (London) Ltd.

The main exhibit by G. A. Harvey & Co. (London) Ltd. was a 20-ton jacketed autoclave, one of four under construction by Harveys to the order of Howards of Ilford Ltd. for the manufacture of industrial chemicals by a high-pressure hydrogenation method. The shell of the autoclave is made of 1½-in. stainless clad steel, of 6 ft inside diameter and 11 ft in height, and is fully stress-relieved. The dished and flanged ends were spun on a "Rotarpress" machine and, on completion, the shell was hydraulically tested to 825 psi.

A multi-bladed impeller, driven by a 50-hp motor, mixes the contents of the autoclave at 120 rpm under a working pressure of 500 psi and at temperatures up to 200°C. A "Flexibox" mechanical seal is fitted at the top of the autoclave where the impeller spindle enters. The impeller was also made by Harveys but, owing to height restrictions at the Exhibition, was displayed unfitted at the foot of the vertical autoclave.

Other exhibits by Harveys included two scale models, one being a part-sectioned model of a fractionating column used in the oil-refining industry and typical of many supplied by the company, while the other was a model of the Rolls Royce jet-engine test plant, for which Harveys were responsible for the design, fabrication, and erection of test cells, pressure vessels, and ducting.

Lee, Howl & Company Limited

Of the exhibits by Lee, Howl & Co. Ltd., of Tipton, Staffs., the new 2 in./2½ in. "Hypersilid" chemical pump was of major interest. Made from silicon-iron castings manufactured by Bradley & Foster Ltd., of Darlaston, this pump (Fig. 6.) is suitable for the chemical and petro-chemical industries, as well as for installation in trade-effluent treatment plants in industry generally, and is designed for handling such corrosive liquors as sulphuric acid at any temperature or concentration, and nitric, acetic, formic, phosphoric, and many other acids. Maximum outputs at 2900 rpm range from 187 gpm with an 80-ft head to 75 gpm with a 153-ft head with maximum impeller diameter, and from 150 gpm with a 51-ft head to 65 gpm with an 86-ft head with minimum impeller diameter.

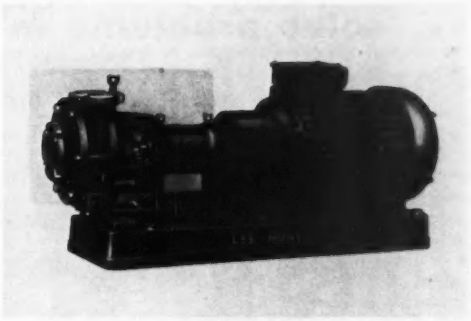

Fig. 6.

No wear rings are fitted, the running clearance of the impeller being generous, so as to avoid a rapid loss in pumping efficiency from wear and corrosion. Parts in contact with corrosive media are made of silicon iron, while other parts are of high-quality fine-grain grey-iron castings. The pump shaft is made of "Staybrite" steel and is adequately protected against liquid drippings by a high-silicon-iron wearing sleeve extending through the whole depth of the stuffing box. The impeller and shaft assembly can be removed quickly as a unit through the pump casing, without disturbing any of the bearings or other components. The casing is of the volute type, made from high-silicon iron of ample thickness to allow for design pressure under corrosive conditions. The pump can be fitted with a suitable soft gland or, if preferred, with a mechanical seal, both types being readily interchangeable.

English Steel Corporation Ltd.

Exhibits from the English Steel Corporation Ltd. embraced representative products of four wholly owned subsidiary companies of the Corporation. Featured among these products were those of the **English Steel Forge and Engineering Corporation, Ltd.** and included a 31-ton forged alloy-steel gearwheel rim of 162-in. diameter for a marine-engine reduction gear, a fully machined forged chrome-molybdenum steel marine rotor, approximately 12 ft in length and 3 ft in diameter, and a nuclear power vessel flange, 77 in. in diameter. Other exhibits from this company included two diesel-engine crankshafts, one 138 in. in length in the as-forged condition, and the other 120 in. in length in the finish-machined condition. Both these crankshafts were made by the continuous grain flow (C.G.F.) process, for which the English Steel Corporation has the sole rights of manufacture in the U.K. Selections of drop forgings and torsion bars for the general engineering industries were also shown by this subsidiary company.

Examples of industrial and mine-car cast-steel automatic couplers were featured by the **English Steel Castings Corporation, Ltd.**, while the **English Steel Spring Corporation, Ltd.** exhibited coil springs for railway bogies, and the **English Steel Rolling Mills Corporation Ltd.** were represented by examples of precision-ground bars and tool steels.

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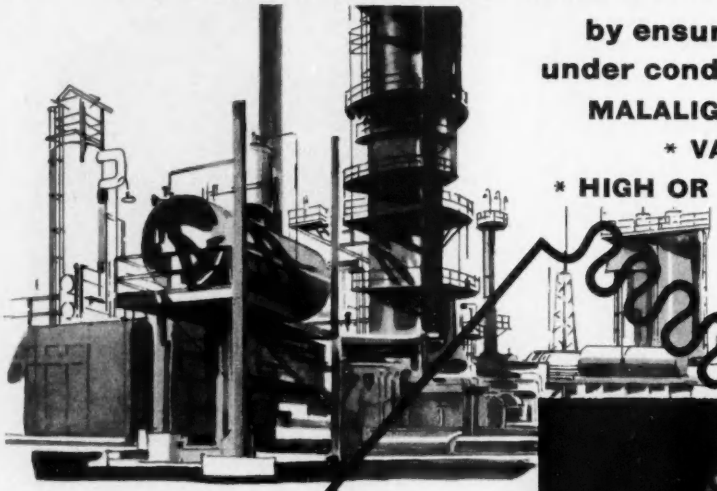

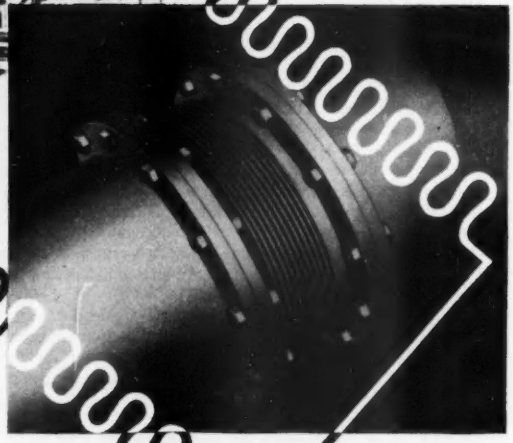

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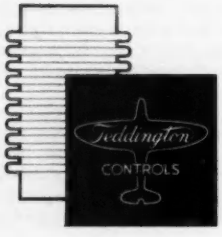

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British Rototherm Co. Ltd.

A comprehensive range of dial thermometers, recorders, and controllers was exhibited by the British Rototherm Co. Ltd., of London, S.W.19, as well as pressure, vacuum, altitude, and hydraulic gauges with dial sizes from 2½ to 8 in., and pressure recorders. These pressure recorders are single- and dual-pen pressure, vacuum, and compound units, and have been designed to match the company's mercury-in-steel temperature recorders, which are available as single- and dual-pen units in normal and portable versions, and as wet- and dry-bulb models.

Bi-metal thermometers included a high-temperature unit specially designed for diesel-engine use, and rigid-stem thermometers with dial sizes from 1 to 7 in. in a wide variety of temperature ranges, styles, stem-lengths, and diameters, for most engine-room, marine, boiler-house, and associated purposes, as well as maximum/minimum and control/alarm thermometers and special designs for most industrial applications.

Mercury-in-steel thermometers were represented by a range of distant-reading and rigid-stem models, with dial sizes from 4 to 10 in., for wall, panel, or bracket mounting, with bulbs and capillaries to suit requirements, as well as edgwise-scale distant-reading types, maximum/minimum and control/alarm thermometers and a number of types for special applications. Also, a wide range of distant-reading and rigid-stem vapour-pressure thermometers, with dial sizes from 2½ to 8 in., were shown, including special-purpose, maximum/minimum, and control/alarm models.

Pioneer Oilsealing and Moulding Co. Ltd.

Exhibits from the Pioneer Oilsealing and Moulding Co. Ltd., of Colne, Lancs., included a comprehensive display of O-rings, precision-ground rectangular-section rings, rotary shaft seals (single- and double-lip), and a range of silicone and fluorinated synthetic rubbers, as well as normal synthetic-rubber products. In addition, "Nu-Lip" rings were specially featured on a sectioned power-assisted steering-box by Hydrosteer, of Luton, Beds.

Two new additions to the company's extensive range of fluid-sealing products were also exhibited, these being the "Wycollen" simple carbon face seal, and a new labyrinth seal. The "Wycollen" seal is a low-pressure springless unit of basically simple construction and is suitable for applications ranging from gearbox seals to washing-machines. The new labyrinth seal has been developed for use in place of conventional metal labyrinth seals on conveyor idlers or for applications where arduous conditions are encountered, such as tractor idler roller seals.

William Kenyon & Sons Ltd.

A wide range of power-transmission appliances exhibited by William Kenyon & Sons Ltd., of Dukinfield, Cheshire, included a selection of high-quality standard V-belts and taper-bushed pulleys, and a range of normal pin- and spring-type flexible couplings, as well as the new "Flexsil" coupling, which is a simple, efficient, and versatile unit made in four sizes for all drive applications up to 100 hp. This coupling, which can satisfactorily accommodate angular misalignments up to 5 deg. and has good damping properties, utilizes a very strong and flexible rubber disc moulded around synthetic tension members.

Other interesting exhibits included the "Shaft King" shaft-mounted reduction gear, which is manufactured under licence from the American Pulley Company, of Philadelphia, Pa. This unit, which is available in six sizes and in two ratios of 13 : 1 and 20 : 1, has a concentric-shaft construction and can be fitted with a positive mechanical overload release, affording complete protection to the prime mover and to any driven machinery. In addition to this overload release, the unit can also be fitted with an internal backstop, which can be used, for instance, to prevent backward movement of conveyors and elevators in the event of a stoppage.

Of special interest were two new belt drives, these being the "Powergrip" drive and the "Poly-V" belt. The "Powergrip" drive, which operates with virtually 100% mechanical efficiency, has a toothed belt running over grooved pulleys, and is capable of operating at speeds up to 16,000 fpm. The drive is almost noiseless in operation.

The "Poly-V" belt is a V-type belt of unit construction, but has 40% higher power capacity than a standard V-belt. The belt, which has marked ability to absorb shock loads and is ideally suited for use with heavy or pulsating machinery, completely eliminates the differential driving problem so often encountered with standard V-belt drives.

Investigation into the Phenomenon of Seizure

(*Concluded from page 91*)

tendency of the softer metal of a pair is the more important. When dry friction is present at some points, there is always a transfer of the softer onto the harder metal. The contact of clean surfaces, or dry friction, occurs under lubricated conditions as a result of high temperatures or large plastic deformation. Transfer of metal can be a result of seizure or mechanical interlocking and the shearing of asperities on the softer metal. As a result of this transfer, there is friction between the same metal, so that the tendency of the metal itself to seize is very significant.

The process of friction is very complicated, since there are on the surfaces various adsorbed films and oxide films. The adsorbed films can be removed or neutralized by high temperatures at the points of real contact. The oxide films, which as a rule are very brittle, can be demolished by plastic deformation of the underlying metal. All these factors have a big influence on seizure and on the resulting damage to the surfaces.

It is quite possible that, in some cases, a reason for the damage to surfaces by friction, referred to as scuffing, galling, and scoring, and also build-up of metal on tools during cutting, is not seizure, but a simple mechanical interlocking of asperities. This is very easy to imagine in the case of metals which work-harden readily, but usually the cause of damage is seizure.

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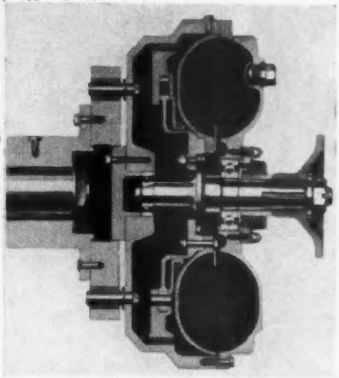

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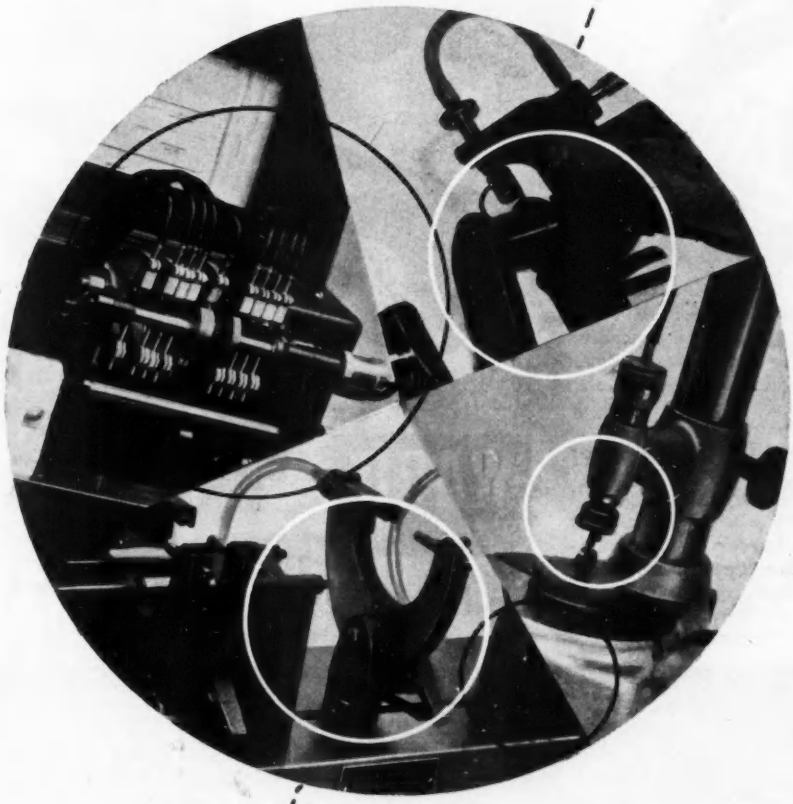

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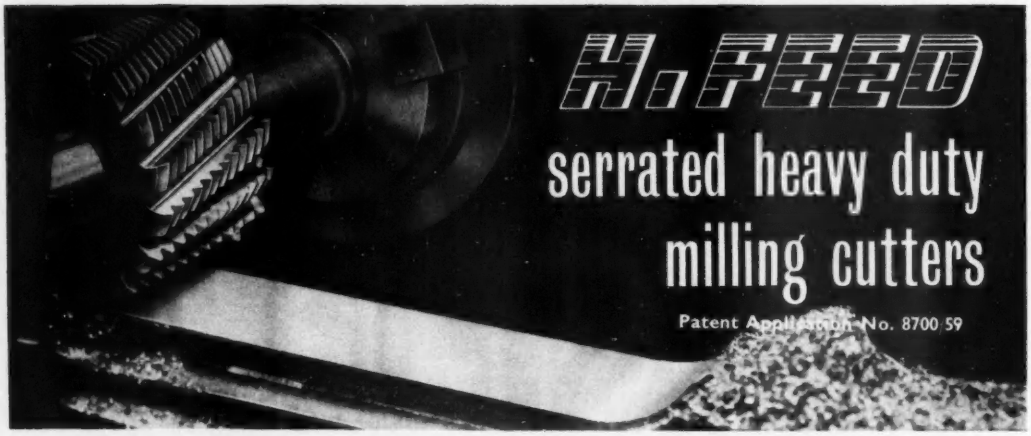

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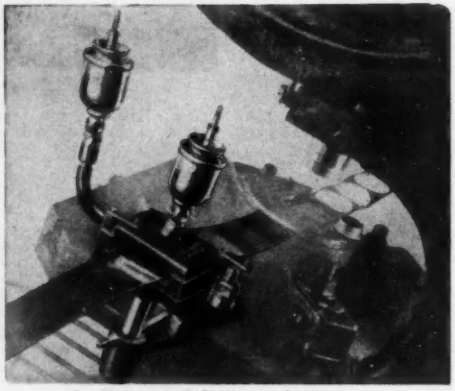

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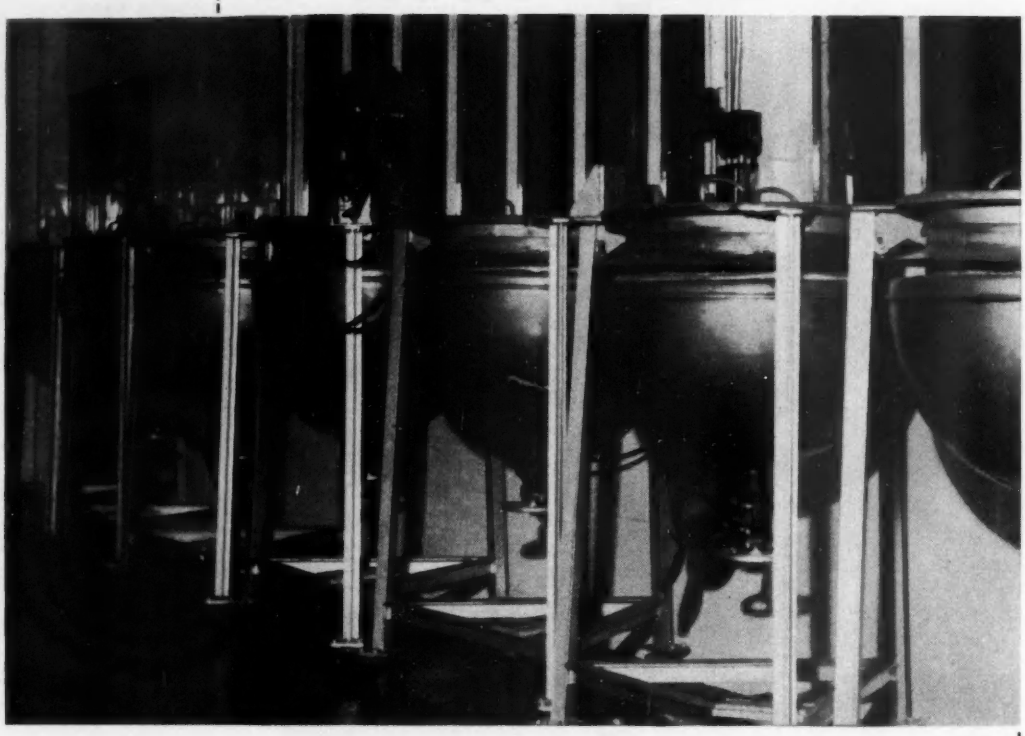

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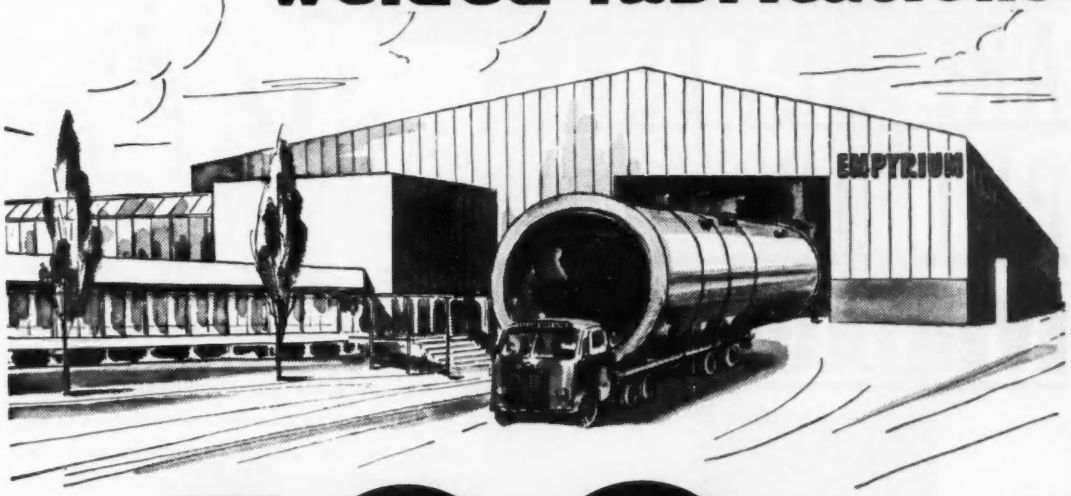

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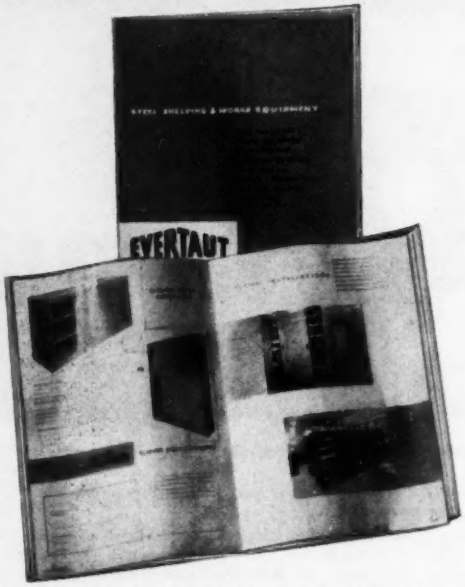

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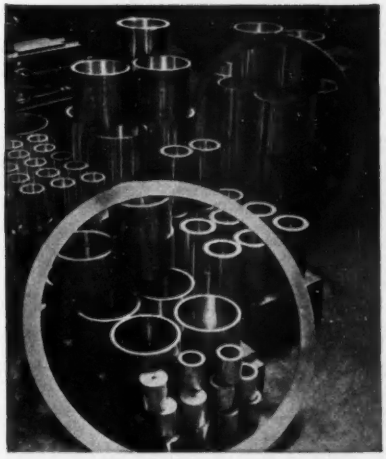

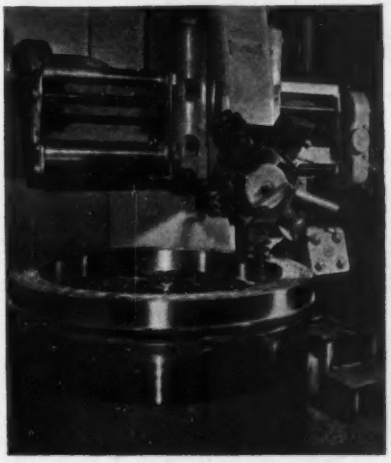

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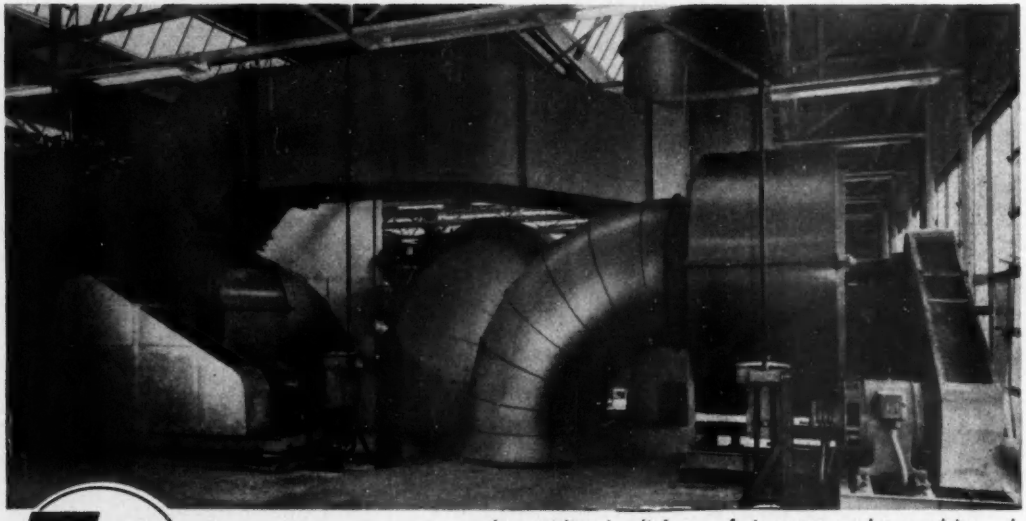

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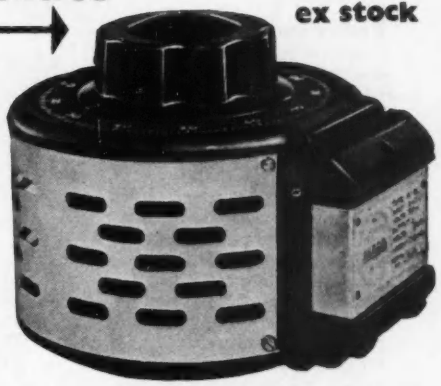

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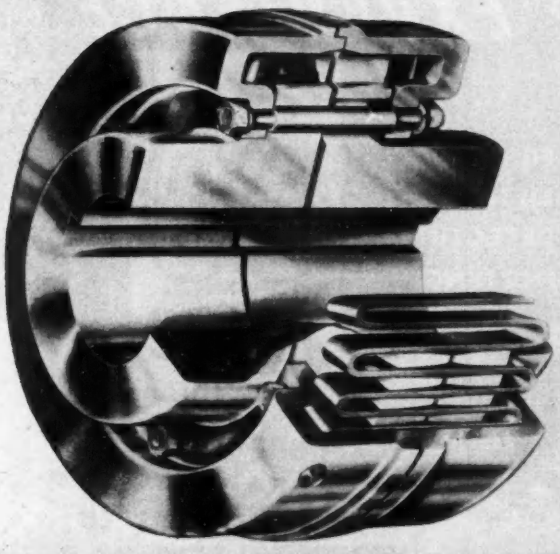

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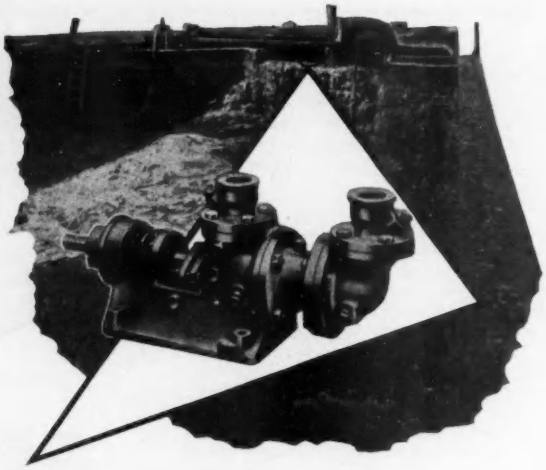

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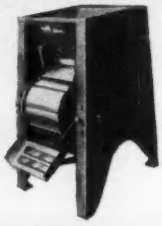

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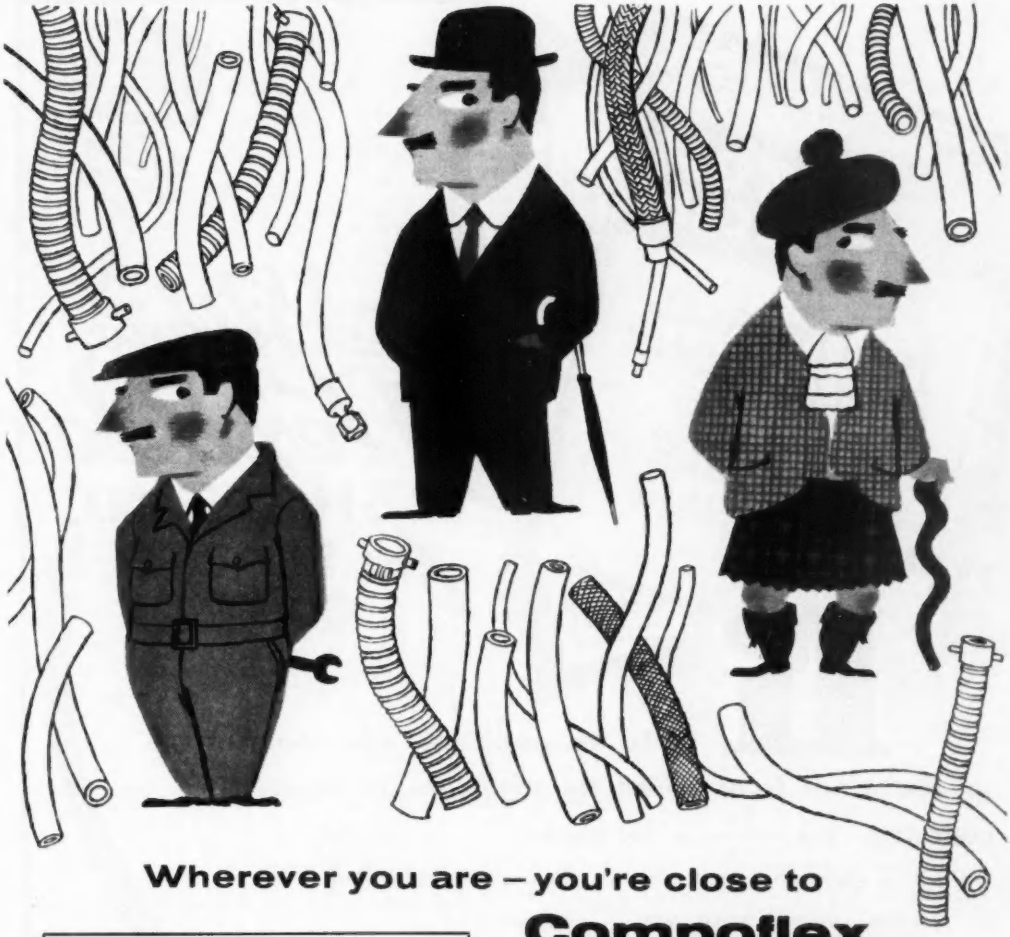

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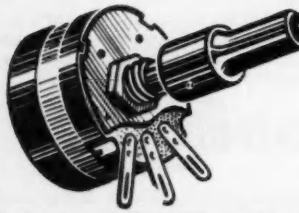

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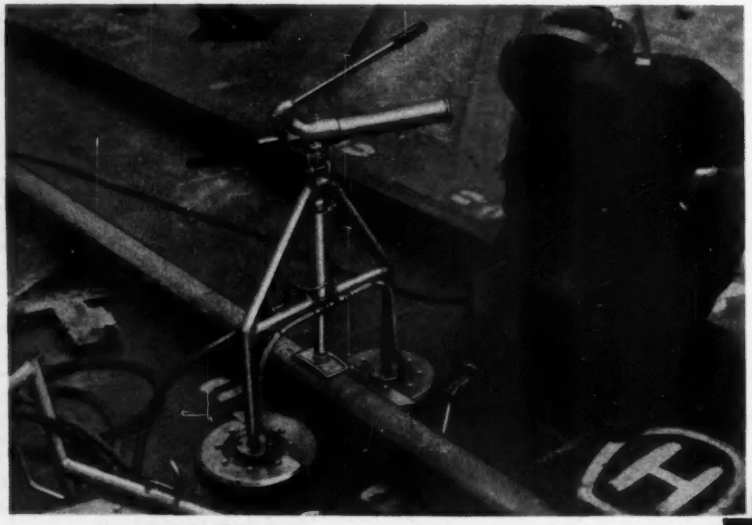

Below:

"Via-Vac" Mobile Type I Machine in operation in a Clydeside Yard, clamping for tack-welding. This model is specifically designed for shipyard use and will handle sections up to 17" in height, with a clamping thrust of 7,280 lbs. from the standard flexible suction pads. Gross weight of machine: 220 lbs. (99 kg.)

Above:

"Via-Vac" Mark II lightweight portable model clamping for tack-welding. This model will accommodate 9" high sections with a clamping thrust of 2,000 lbs. from the standard 10" diameter flexible thrusting pads. Gross weight of power unit and clamping device combined: 114 lbs. (51 Kg.)

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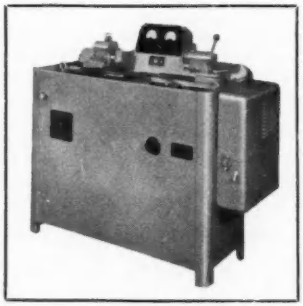

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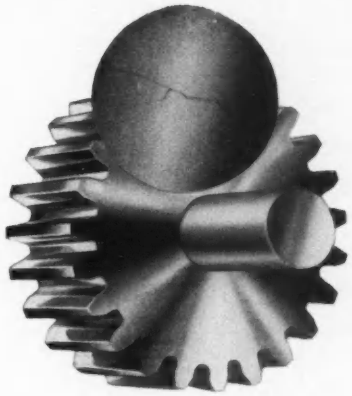

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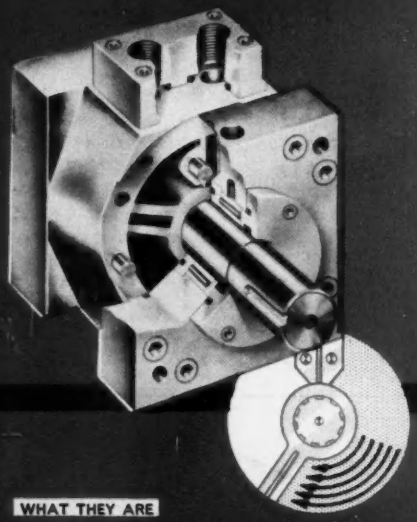

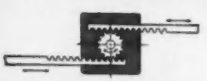

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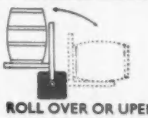

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TURN OR OSCILLATE

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Opening and closing doors.
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indexing, feeding, transferring, clamping, locating, turning over.
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Pipe and tube bending.
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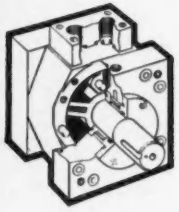

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3. *Working mechanism fully sealed from dirt.*

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